PB-219 372

Analysis of Airport Solid Wastes and Collection Systems

San Francisco International Airport

prepared for

San Francisco City and
County Airports Commission
Environmental Protection Agency

1973

Distributed By:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

EPA-SW-48D-73

PB 219 372

ANALYSIS OF AIRPORT SOLID WASTES AND COLLECTION SYSTEMS

SAN FRANCISCO INTERNATIONAL AIRPORT

This final report (SW-48d) on work performed
under solid waste management demonstration grant no. G06-EC-00294
to the City and County of San Francisco Airports Commission
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1973

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA-SW-48D-73

2.

3. Recipient's Accession No. PB-219 372

4. Title and Subtitle

Analysis of Airport Solid Wastes and Collection Systems; San Francisco Airport

5. Report Date 1973

6.

7. Author(s)

Metcalf & Eddy, Inc.

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Airports Commission
City and County of San Francisco
San Francisco International Airport
San Francisco, California 94128

10. Project/Task/Work Unit No.

11. [illegible]/Grant No. G06-EC-00294

12. Sponsoring Organization Name and Address

U.S. Environmental Protection Agency
Office of Solid Waste Management Programs
Washington, D.C. 20460

13. Type of Report & Period Covered Final

14.

15. Supplementary Notes

16. Abstracts The two primary objectives of this project were to develop basic information on solid wastes generated at San Francisco International Airport and to study alternative collection, transfer, and transportation systems that might demonstrate engineering feasibility and economic benefit. The weight and composition of solid wastes were derived from field data gathered from passenger terminals, air freight areas, including mail service facilities, aircraft service centers, and aircraft maintenance bases. Total quantity was 207 tons per week. Questionnaires were sent to national airports to determine their operating levels and the levels were then compared to those at San Francisco to ascertain whether the data derived there would be applicable on a nationwide basis. The report describes two collection systems of potential economic benefit to the airport complex that were selected from various alternatives evaluated. One is a modification of the existing system--wider use of compactors, shredders, debris boxes. The other is a completely new system--installation of a wheel mounted portable equipment system. Either alternative requires that the airport exercise greater operational control.

17. Key Words and Document Analysis. 17a. Descriptors

*Refuse, *Airports, Collection, Maintenance equipment, Systems management, Operating costs, Questionnaires

17b. Identifiers/Open-Ended Terms

*Solid waste management, Waste characteristics, San Francisco (California), San Francisco International Airport

17c. COSATI Field/Group 13B

18. Availability Statement

Release to public

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page UNCLASSIFIED

21. No. of Pages

22. Price

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

An environmental protection publication in the solid waste management series (SW-48d)

This report has been reviewed by the U.S. Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency nor does mention of commercial products constitute endorsement or recommendation for use by the U.S. Government.

PREFACE

This is the first published study of airport solid wastes. It focuses on the quantities, kinds, and sources of the wastes and their storage, collection, and transfer. Actual field data was gathered at the San Francisco International Airport. In addition, data was assembled from 36 other major airports who responded to mailed questionnaires. Eight of the 36 questionnaires were supplemented with personal interviews.

Located some 14 miles from downtown San Francisco on a 3,000-acre site, San Francisco International supports commercial, general, and some minor military traffic. The fourth busiest airport in the United States and the fifth busiest in the Free World, it is typical of the modern aviation complex--the isolated, self-contained, expanding institution whose wastes differ in content from the usual residential and municipal solid wastes.

San Francisco International handles as many as 2,000 aircraft movements daily. On an annual basis, these represented, in 1971, some 15 million passengers moving through the airport, 436 thousand tons of mail and air cargo that were processed--and almost 15 thousand tons of solid wastes that were generated.

Although the specific locale for this study was the San Francisco Airport, the premise of the study is applicable to other commercial airports. Through a thorough understanding of waste sources, quantities, and characteristics, and how these are related to levels of operation (i.e., numbers of flights, passenger load, air cargo tonnage), basic planning factors can be developed for a management system for handling both existing and projected waste loads. It also could guide in selecting flexible and economical methods for storing, collecting, and transporting refuse. This study did not extend to disposal, and processing was evaluated only as it related to storage and collection.

R. Kent Anderson served as the Project Officer for the Office of Solid Waste Management Programs. Robert G. Lee was the Project Director for the Airports Commission, City and County of San Francisco, and Hilary Theisen was the Project Manager for Metcalf & Eddy, Inc.

--Clyde J. Dial, *Director*
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TABLE OF CONTENTS

Chapter		Page
1	SCOPE OF THE PROJECT	1
	Authorization	1
	Scope of Work	1
	Approach to the Project	3
2	SUMMARY OF FINDINGS	5
	Solid Waste Characteristics	5
	Alternative Collection and Transportation Systems	7
3	PRESENT CONDITIONS	16
	Study Area Characteristics	16
	Airport and Tenant Activities	18
	Existing Solid Waste System	20
	Solid Waste Handling Costs	32
	Classification of Wastes by Source	33
	Weighing Program	33
	Physical and Chemical Characteristics	38
	Survey of Other Airports	41
	Purpose and Scope	41
	Solid Waste Systems	42
	Management Methods	45
	Adequacy of the Existing System	46

TABLE OF CONTENTS (continued)

Chapter Page

4 POTENTIAL MANAGEMENT METHODS 48

Introduction 48

Types of Management Methods 48

Method 1 48

Method 2 49

Method 3 50

Important Planning Considerations 51

Implementation 51

Operations and Environment 52

Finances 53

5 POTENTIAL COLLECTION AND HANDLING METHODS 55

Introduction 55

Collection 55

Containers 56

Frequency of Collection 57

Collection Routes 58

Collection Vehicles 59

Crew Size 62

Transport 62

Pipelines 63

Vehicles 65

TABLE OF CONTENTS (concluded)

Chapter		Page
5 (cont'd)	Processing	67
Compaction	67
Shredding	68
Separation	69
High-Compression Baling	69
Incineration	70
Transfer	71
6	ALTERNATIVE COLLECTION SYSTEMS	73
Present and Future Demands for Solid Waste Systems	73
Selected Collection and Handling Methods	76
Potential Locations for Equipment	78
Selected Management Methods	80
System Development	81
Alternative 1	83
Alternative 2	88
Cost Analysis	93
Conclusion	96
Appendix	
A	WEIGHING AND SAMPLING TECHNIQUES	98
B	SAMPLE OF SURVEY QUESTIONNAIRE	121
C	REGULATIONS	123

FIGURES

Number		Page
1	San Francisco International Airport	17
2	Refuse Storage Containers at Passenger Terminals	26
3	Refuse Storage Containers at Air Freight Area	28
4	Refuse Storage Containers at Aircraft Maintenance Base	31
5	Typical Compaction Trailer and Tractor	66
6	Typical Cross-section View of Small Transfer Station	72
7	Projected Quantity of Airport Refuse, 1970-1985	74
8	Alternative Collection System 1	84
9	Alternative Collection System 2	89

TABLES

Number		Page
1	Existing Solid Waste System, San Francisco International Airport, July 1971	22
2	Collection Vehicles and Internal Routing Used by Private Hauler in Existing Solid Waste System, San Francisco International Airport, July 1971	24
3	Sampling Data - Summary of Quantities of Solid Wastes Collected in One Week, San Francisco International Airport, July 1971	34
4	Sampling Data - Quantities of Solid Wastes Discharged per Passenger, San Francisco International Airport, July 1971	37
5	Sampling Data - Solid Waste Components by Source, San Francisco International Airport, July-November 1971	40
6	Sampling Data - Chemical Characteristics of Organic Solid Wastes by Source, San Francisco International Airport, July-November 1971	40
7	Selected Results from National Airport Survey, November 1971	43
8	Collection and Handling Equipment Costs	77
9	Equipment Evaluated for Use at San Francisco International Airport	82
10	Equipment and Manpower Requirements and Capital Costs for Alternative 1	86
11	Equipment and Manpower Requirements and Capital Costs for Alternative 2	90
A-1	Sampling Data - Quantities of Solid Wastes from Passenger Terminals by Component, San Francisco International Airport, July 1971	103

TABLES (continued)

Number Page

A-2 Sampling Data - Confidence Range on Data from Passenger Terminals by Component, San Francisco International Airport, July 1971 104

A-3 Sampling Data - Quantities of Solid Wastes from Air Freight Area by Component, San Francisco International Airport, July 1971 107

A-4 Sampling Data - Confidence Range on Data from Air Freight Area by Component, San Francisco International Airport, July 1971 108

A-5 Sampling Data - Quantities of Solid Wastes from Aircraft Service Center by Component, San Francisco International Airport, August-December 1971 110

A-6 Sampling Data - Percent Distribution of Wastes Comprising Aircraft Service Center Wastes by Component, San Francisco International Airport, August-December 1971 111

A-7 Sampling Data - Confidence Range on Data for Meal Service Wastes by Component, San Francisco International Airport, August-September 1971 112

A-8 Sampling Data - Confidence Range on Data for Aircraft Wastes (Excluding Meal Service Wastes) by Component, San Francisco International Airport, August-September 1971 112

A-9 Sampling Data - Confidence Range on Data for Service Buildings by Component, San Francisco International Airport, December 1971 113

A-10 Sampling Data - Quantities of Solid Wastes from Aircraft Maintenance Base by Component, San Francisco International Airport, August 1971 115

TABLES (concluded)

Number		Page
A-11	Sampling Data - Confidence Range on Data from Aircraft Maintenance Base by Component, San Francisco International Airport, August 1971	117
A-12	Sampling Data - Chemical Characteristics of Organic Solid Wastes by Source and Sample Number, San Francisco International Airport, July-November 1971	119

Chapter 1

SCOPE OF THE PROJECT

Authorization

Many airports across the nation are developing into major commercial complexes, often remote from urban areas, which are generating increasing quantities of solid wastes. Recognizing the need for better solid waste systems, San Francisco International Airport undertook this project to assist in the development of solid waste planning.

The project was authorized by the City and County of San Francisco through its Airports Commission. Because the work to be accomplished would have significance for airport operations in other parts of the country, a federal demonstration grant was awarded to assist in the funding of the project. The contract between the City and County of San Francisco and Metcalf & Eddy, Inc. (M&E), was executed in March 1971. A period of 12 months was granted for the study.

Scope of Work

The two primary objectives of this demonstration project were (1) to develop basic information on solid wastes generated at San Francisco International Airport, and

(2) to study alternative collection and transportation systems that might demonstrate engineering feasibility and economic benefit. To accomplish these objectives, the following major work items were delineated in the contract:

1. Develop basic information as to the quantities, characteristics, and sources of solid wastes generated at the San Francisco International Airport.

2. Develop facts regarding the above information as related to levels of operation, such as number of flights, passenger load, air cargo tonnage, etc., for predicting future solid waste loadings. This information would have national significance in that it could be used to compute similar information for other commercial airports.

3. Study alternative systems for collection, transfer, and transportation of solid wastes.

4. Select the most feasible system from the standpoint of suitability, flexibility, and economy, and prepare a cost estimate for construction of facilities to demonstrate a system of engineering feasibility and economic benefit.

Although not specifically identified in the contract scope, a future planning period up to 1985 was selected to study alternative collection and transportation systems.

It should be noted that, because of funding limitations, an evaluation of solid waste disposal systems was not included in this project. A practical evaluation of collection and transportation systems, however, must include a limited evaluation of processing systems as an aid to both collection and disposal systems. Therefore, processing and disposal systems were considered, but only as they relate directly to collection and transportation.

Approach to the Project

The management of solid wastes is becoming an important element in the overall operations of large commercial airport complexes. The increasing numbers of aircraft passengers, coupled with the trend toward throwaway packaging and meal utensils, are producing significant increases in solid waste quantities. As these wastes continue to increase it becomes more necessary to use predictive methods in management planning. Such methods are not now available. Only when a thorough understanding of waste sources, quantities, and characteristics is achieved can effective waste management methods be developed.

The approach to achieving an understanding of airport wastes for this study was one of utilizing the knowledge of both airport engineers who were familiar with operational requirements and of consulting engineers and planners experienced in solid waste systems. A work program was developed which split the tasks of this project between the two teams. All field data and airport planning data were accumulated by airport personnel under guidelines prepared by the consultant. Data evaluation and waste management system development were accomplished by the consultant. Close coordination was maintained during all phases of the work. In this way, the knowledge and capability of each team was used fully so that practical and useful results could be attained.

Because this was to be the first in-depth study of airport solid wastes, a broad survey of many national airports was included. The approach used was one of mailed questionnaires to airports to determine their operating levels. These levels were then compared to those at San Francisco International Airport to ascertain whether solid waste data derived there would be applicable on a nationwide basis. If useful results would be achieved, the planning process for other airports would be greatly accelerated.

Chapter 2

SUMMARY OF FINDINGS

The significant conclusions and findings of this study are presented in this chapter. Detailed background information concerning the findings is presented in following chapters. As identified in Chapter 1, the main objectives of the study were (1) to develop basic information on solid wastes generated at airports, and (2) to study alternative collection and transportation systems. The findings are presented accordingly in two lists.

Solid Waste Characteristics

1. Sources of solid wastes at airports are definable and are similar throughout large airport complexes around the United States. These sources were classified, both by function and by geographic location within the airport complex, into the following four types of facilities:
    - Passenger terminals
    - Air freight area, including mail service facilities
    - Aircraft service centers
    - Aircraft maintenance bases
2. Solid waste characteristics (weight and composition) were identified for each of the four sources.

The characteristics were derived through field data gathering only at San Francisco International Airport. The significant characteristics of weight and composition for each source, based on data representing a composite week of field observations, include the following:

	Weight, tons per week	Primary composition type
• Passenger terminals	68.7	70 percent paper
• Air freight area	29.8	46 percent paper 17 percent wood 10 percent plastics
• Aircraft service centers	133.2	34 percent food 32 percent paper 12 percent metal 10 percent plastics
• Aircraft maintenance base	55.6	51 percent paper 15 percent food 10 percent plastics

Demolition material, normally generated in large quantities at an airport complex, was not generated during the sampling period and therefore could not be measured.

3. The unit generation values derived for each source are:

- Passenger terminals - 0.53 pound per passenger
- Air freight area - 7.10 pounds per ton of cargo

- Aircraft service centers:
  - Composite of all activities - 1.02 pounds per passenger
  - Aircraft flights including meal service wastes - 2.51 pounds per passenger
  - Aircraft flights excluding meal service wastes - 0.54 pound per passenger
- Aircraft maintenance base - 2.19 pounds per employee per day

4. The total quantity of refuse generated on the airport complex on a holiday (Labor Day) does not fluctuate significantly from that on a normal weekday. A possible explanation is the balancing effect of lower work activity in the maintenance base and service centers versus higher passenger and cargo activity at the terminals and air freight area.

Alternative Collection and Transportation Systems

1. The total quantity of refuse generated at San Francisco International Airport is 287 tons per week. This quantity is projected to increase to 500 tons per week by 1985. These figures are based on the following basic data: passenger loading approximately 15 million in 1971, projected to increase to 32 million by 1985; air cargo approximately 436,000 tons in 1971, projected

to increase to 1,660,000 tons by 1985; employee levels at the maintenance base approximately 8,000 to 10,000, projected to increase only slightly by 1985.

2. Existing solid waste systems are controlled individually by each airport tenant, except in the terminals where the airport authority controls the system. There has been very little coordinated planning for the airport solid waste systems under this fragmented control condition. Although many different types of efficient equipment are used, a highly inefficient loose-garbage room exists in the South Terminal. This is an example of inadequate and uncoordinated planning. The major coordination has been achieved by a single hauler who serves all tenants on the airport. The hauler removes all wastes from the airport for disposal at a sanitary landfill located about 15 miles from the complex.

3. Regarding the control of solid waste systems at other airports, selected results from the survey revealed that 58 percent of the airports had no solid waste systems operated by a public agency, while 33 percent had a combined public-private collection system. In 61 percent of the airports each tenant makes his own contract arrangements with the private hauler.

4. The existing solid waste collection system has the following equipment: 30- to 50-gallon storage cans,

2-cubic yard back-end loading storage containers, 2- to 6-cubic yard front-end loading storage containers, 10- to 40-cubic yard debris boxes, a loose-refuse room, stationary compactors, back-end loading trucks, and tilt-frame trucks. This type of collection system equipment is common to most of the other airports contacted during the survey.

5. Demolition material is hauled in debris boxes or standard earthwork construction vehicles (dump trucks). Wood wastes, normally placed in debris boxes, are disposed of off the airport at the sanitary landfill. Dirt, broken concrete, and broken asphalt pavement are disposed of on the airport in areas where the existing land has subsided and benefits from filling.

6. The existing system removes all refuse from the airport with only minor interference with airport operations and limited litter or debris. The system does require frequent truck traffic in the terminal and passenger loading pier area, increasing the potential for congestion and equipment damage. Under these conditions, the cost of the present system could be higher than that of a system utilizing more efficient equipment. The cost of the present system of collection and disposal is approximately $20,000 per month, or about $16.10 per ton of refuse collected.

7. Collection and handling methods selected as feasible for evaluation at San Francisco International Airport as alternatives or modifications to the existing system were: stationary compactors, debris boxes, wheel mounted cans (compacted and uncompacted), front-end loading trucks, towing tractors, and tilt-frame trucks. Because of their potential benefits to the collection system, the following processing methods were considered: shredding, incinerating, and wet pulping.

8. Two collection systems of potential economic benefit to the airport complex were selected from the various alternatives evaluated. Both offer significant advantages over the existing system, but the final selection should be made by the airport commission as discussed in Item 10. Alternative 1 is a modification to the existing system, incorporating the wider use of stationary compactors, debris boxes, and a shredder for bulky wastes in the air freight area. The equipment might be supplied by private haulers, and system operation might be continued by private haulers. Alternative 1 capital costs are $302,000, and annual costs average $5.20 per ton of refuse handled. Alternative 2 is a completely new collection and transfer system for the airport complex. All existing equipment would be replaced (feasible since most existing

system equipment is owned by the private hauler) by a wheel mounted portable equipment system. This system would serve all tenants and areas of the airport. The equipment would be purchased by the airport and the system would be operated by airport personnel. Alternative 2 capital costs are $164,000 and annual costs average $5.60 per ton of refuse handled.

The annual costs and cost savings for two periods (1971 and 1985) under the existing system, Alternative 1, and Alternative 2 are shown in the following tabulation.

	For 1971 refuse quantity(1)	For 1985 refuse quantity(2)
Existing system		
Annual cost	$128,700	$302,000
Alternative 1		
Annual cost	77,700	182,000
Annual savings compared with existing system costs	51,000	120,000
Alternative 2		
Annual cost	83,200	195,000
Annual savings compared with existing system costs	45,500	107,000

---

(1) 14,900 tons per year for 1971.

(2) 34,900 tons per year for 1985.

9. Alternative 1 has the following advantages over the existing system:

   - Present collection trips could be reduced from 70 trips per week to 54 trips per week, and total time consumed in the airport collection could also be cut approximately by 50 percent (from 51 hours to 24 hours).
   - Lower annual costs would result for all tenants collectively, although each individual tenant might have a higher or lower cost, depending on present in-house collection equipment and contract arrangements.
   - Potential interference with aircraft movement would be greatly reduced.
   - Security within aircraft operating areas would be more easily maintained.
   - Refuse would be delivered to a limited number of collection locations by each tenant, thereby utilizing to a greater degree the in-house equipment (and its flexibility for both refuse hauling and aircraft operations) of each tenant.

Alternative 2 has the following advantages over the existing systems:

- Solid wastes technology is presently evolving at a very rapid rate. More efficient processes may soon be developed. This alternative would be most flexible for adapting to future change.

- Through an integrated management system operated exclusively by the airport, tenants would collectively benefit from lower annual costs and also from future changes in technology that might require a large amount of investment to update the system.

- Although the collection time and number of pickups would be nearly equivalent to the existing system, airport security would be increased under Alternative 2 because airport personnel would be operating on collection routes. Interference with aircraft operations would also be minimized because the towing tractors and containers are approximately the same size as baggage handling equipment widely used around aircraft.

10. On the basis of the reported cost savings, the airport should change its refuse collection procedures. The changes in equipment that have shown a potential for

benefit are related to container size and location. The equipment with the greatest benefit potential has been identified in Alternatives 1 and 2. The final determination of the alternative to be used should be based upon the degree of operational control the airport wishes to maintain over refuse collection operations. Three management methods have been identified and are listed below.

- Method 1 - The airport commission maintains full operational control over the entire refuse handling function (collection, transport, and disposal). All equipment is the property of the commission, and tenants are billed for the service provided.

- Method 2 - The airport commission shares management with the tenants. Shared management ranges from complete control (nonoperational) of management by the airport to 99 percent control by the tenants.

- Method 3 - The airport commission leaves all management, including refuse collection and disposal functions, in the control of each tenant. Only an enforcement control is maintained over the tenants to the extent of safeguarding aircraft movement, the environment, and public health.

If the airport continues with collection service by private haulers, Alternative 1 should be implemented. If operational control by the airport is important, Alternative 2 should be implemented. With either alternative, however, the airport authority should play a stronger future role in controlling its solid waste system.

Chapter 3

PRESENT CONDITIONS

Study Area Characteristics

The San Francisco International Airport is a large commercial airport complex located in San Mateo County, California, approximately 14 miles south of San Francisco. The total land area within the airport boundaries is approximately 3,000 acres. The physical details of the airport complex are shown on Figure 1. With San Francisco Bay as a boundary on two sides, the airport is somewhat remote from population concentrations and associated solid waste producing activities. Commercial and industrial facilities have developed in areas adjacent to the airport, however, and solid waste service is provided in these areas.

As might be expected from the location of the airport along an estuary, the underlying soils of the airport contain significant quantities of decomposing organic materials. This condition causes high rates of soil consolidation and settlement--a factor which must be considered when underground waste collection systems are evaluated.

The configuration of mountains to the west of the airport causes very strong winds during the afternoon and early evening. Such winds are strongest in the summer when ocean fogs move in over the coast mountains. Air temperatures are affected

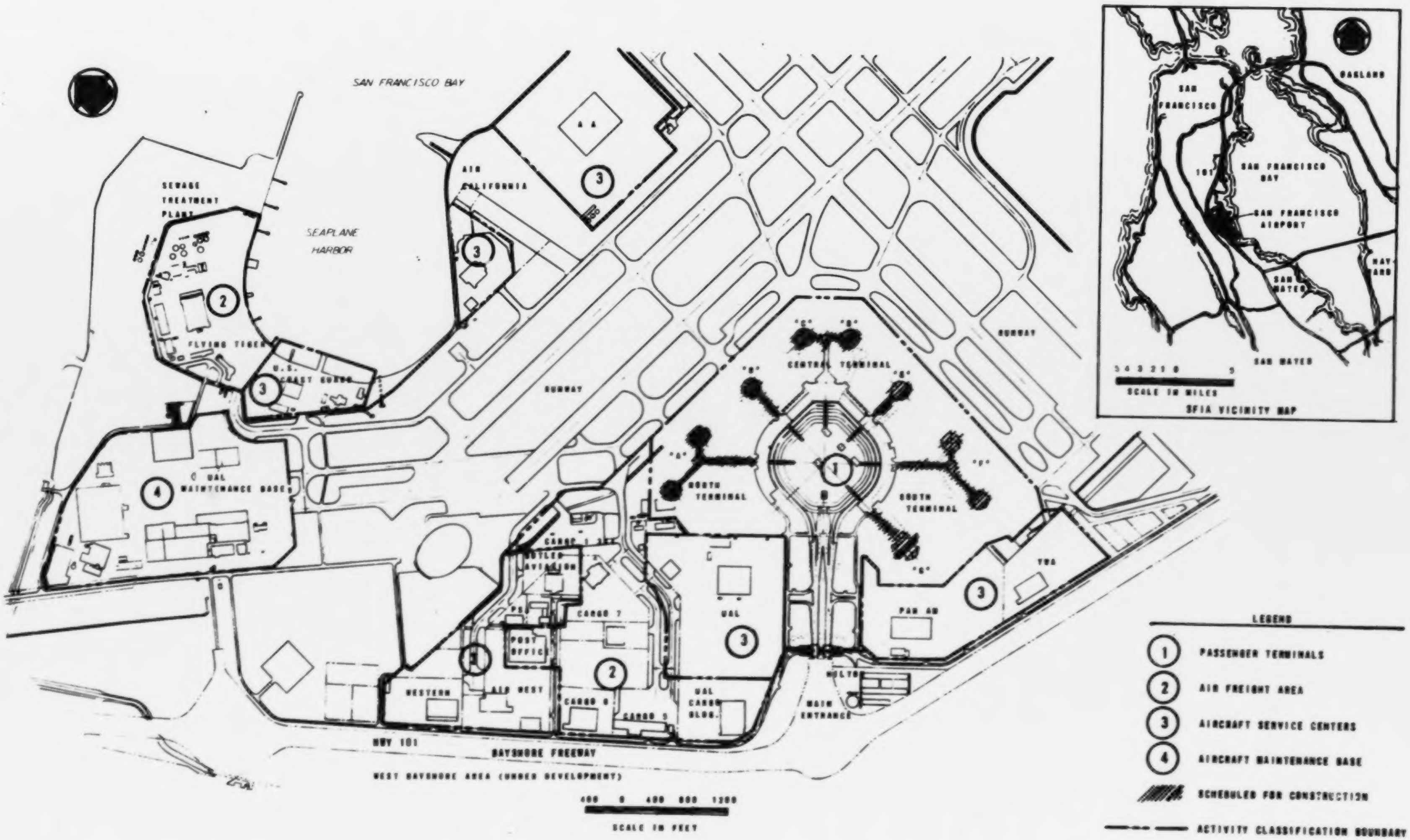

SAN FRANCISCO BAY
SEAPLANE HARBOR
SEWAGE TREATMENT PLANT
FLYING TIGER
U.S. COAST GUARD
UAL MAINTENANCE BASE
AIR CALIFORNIA
A A
RUNWAY
RUNWAY
CENTRAL TERMINAL
NORTH TERMINAL
SOUTH TERMINAL
"A"
"B"
"C"
"D"
"E"
"F"
BUTLER AVIATION
CARGO 7
PS
POST OFFICE
WESTERN
AIR WEST
CARGO 6
CARGO 5
UAL
UAL CARGO BLDG.
MAIN ENTRANCE
HILTON
PAN AM
TWA
HWY 101
BAYSHORE FREEWAY
WEST BAYSHORE AREA (UNDER DEVELOPMENT)
400 0 400 800 1200
SCALE IN FEET
SAN FRANCISCO
OAKLAND
101
SAN FRANCISCO BAY
SAN FRANCISCO AIRPORT
SAN MATEO
HAYWARD
SAN MATEO
5 4 3 2 1 0 5
SCALE IN MILES
SFIA VICINITY MAP
LEGEND
① PASSENGER TERMINALS
② AIR FREIGHT AREA
③ AIRCRAFT SERVICE CENTERS
④ AIRCRAFT MAINTENANCE BASE
▨ SCHEDULED FOR CONSTRUCTION
— - — ACTIVITY CLASSIFICATION BOUNDARY

FIG. 1

SAN FRANCISCO INTERNATIONAL AIRPORT

by these atmospheric conditions, especially in the summer. The average temperature during the summer ranges from 72 degrees during the day to 54 degrees at night. Annual precipitation is approximately 19 inches, and 90 percent of this occurs in the period from November through April.

Airport and Tenant Activities

San Francisco International Airport is one of the busiest in the United States. All major airlines use the facility on a regular schedule. In addition, the airport handles general aviation traffic plus some minor military traffic. Support facilities include major aircraft overhaul shops, aircraft service centers, terminals, and a hotel. Passenger loading (enplaning and deplaning) during 1971 was approximately 15 million. The total amount of air freight and mail in 1971 was approximately 925 million pounds. A significant quantity of solid wastes is generated by support activities for an operation of this magnitude.

There are more than 40 tenants in the airport complex. The majority are airlines providing passenger, air freight, and aircraft service. Other tenants include supplementary passenger service businesses, such as banks, car rental agencies, restaurants, and mail service, and support services for aircraft operations, such as fuel farms, flight kitchens, and flight training. Normally, similar services are located close to each other. Therefore, the tenants may be classified on the basis of their geographic locations within the airport, as well as by their function, into four main sections: (1) passenger terminals, (2) air freight area, including mail service facilities, (3) aircraft service centers, and (4) aircraft maintenance base. The locations of these four main sections are shown on Figure 1.

The passenger terminals (in two separate buildings) provide all types of services that are convenient to and used by passengers. The most significant generation of solid wastes at the terminals takes place in the food and baggage service areas of each airline.

The air freight area, which provides all air freight and mail services, generates a large quantity of solid wastes consisting mostly of bulky packing and shipping materials.

The aircraft service centers, spread around the airport complex, are hangars that provide aircraft supplies and minor maintenance. Interior cleaning service for arriving planes is also provided by a crew from the service center. These cleaning wastes are brought back to the service center for future collection.

The aircraft maintenance base provides services for major repairing and overhaul of aircraft. There is only one such base at San Francisco International Airport, as shown on Figure 1. The base, a facility of United Air Lines, consists of three major departments: Maintenance, Engineering, and Supply.

The complete base is similar to an industrial plant, and the solid wastes generated are typical industrial wastes (oil sludges, plastics, metals, paper, wood cratings).

The airport has experienced rapid growth in the past 10 years. Future planning by airport tenants will be based upon this growth pattern, resulting in continued construction activities during the near future. Limited space availability will eventually stop area expansion, but remodeling of facilities to fit new aircraft equipment will continue. Future planning does not include any significant changes (such as an additional maintenance base for a second airline) by any of the existing tenants. Passenger loading piers and terminal facilities are presently being expanded, however, and this will substantially increase the generation of solid wastes at the terminals.

Existing Solid Waste System

The existing system for airport solid wastes comprises three major parts: (1) in-house handling, (2) collection and transport, and (3) disposal. In-house handling is defined as the movement of refuse by a tenant (includes airport operations personnel) to a collection point for handling by a second party. It is normally performed by each tenant, except in specific areas of the passenger terminals such as ticket counters and rest rooms, where it is performed by airport operations personnel as a part of the utility service. Collection and transport, defined as the picking up and movement of refuse after in-house handling, as well as disposal, are presently provided by a private hauler. The hauler collects all wastes generated at buildings and hangars inside the airport complex and transports them to a privately-owned landfill site located about 15 miles from the airport.

At present, solid waste systems are managed by many independent tenants. The airport management, on behalf of tenants in the terminal only, contracts with the South San Francisco Scavenger Company to collect and transport the solid wastes generated from the terminals and the passenger loading piers. Other than this, the airport management has not become involved in the management of solid wastes generated by tenants. Historically, each tenant has managed its solid waste activities independently without consulting with the airport management or other tenants. Because few private haulers are available for contract hauling in the vicinity of the airport, almost all tenants have contracted with the same one. The airport management has never attempted to integrate all activities into a single system.

The existing solid waste system at the airport is described in Tables 1 and 2. The data shown in Table 1 include the types of containers used by the tenants, the types of collection vehicles used by the private hauler, and the collection frequency. As a general practice, containers are furnished by the private

Table 1

EXISTING SOLID WASTE SYSTEM
San Francisco International Airport
July 1971

Source and location	Tenant	Containers, number and size (cy)	Collection vehicle			Collection frequency
			Front-end loader	Back-end loader	Pull-on truck	
Passenger terminals:						
1. Central and South Terminal buildings	Airport operation	14 - 5'x2'x3' (1) 10 - 3'x2'x1.5' (1/3)		X X		3-4/day
	Avis Rent-a-Car	1 - 5'x2'x3' (1)		X		3-4/day
	Airway Equip. Rental	1 - 5'x2'x3' (1)		X		3-4/day
	Hertz	1 - 5'x2'x3' (1)		X		3-4/day
	Host International	6 - 5'x2'x3' (1) 3 - 5'x2'x3' (1)		X X		3-4/day
	National Car Rental	1 - 5'x2'x3' (1)		X		3-4/day
	DeLaval	Barrels		X		
2. Airport parking	Airport Garage	2 - 5'x2'x3' (1)		X		3-4/day
	Yellow Cab	1 - 5'x2'x3' (1)		X		3-4/day
3. Miscellaneous	Contractor H.V. Olsen	1 - 5'x2'x3' (1)		X		3-4/day
	Bank of America	Barrels		X		3-4/day
4. Pier F	Western Airlines	3 - 6'x5'x5' (6) 2 - 6'x5'x5' (6)	X X			3-4/week
5. Pier E	PSA	1 - 6'x5'x5' (6)	X			6-7/week
6. Pier D	Delta	1 - 12'x7'x5' (14)			X	2-3/week
7. Pier C	Serv-Air-Calif.	1 - 5'x2'x3' (1)		X		3-4/day
Air freight area:						
1. Cargo 1	Miscellaneous Tenants	1 - 12'x7'x5' (14)			X	2-3/week
2. Cargo 3	Airlift International	1 - 6'x4.5'x4.5' (5)	X			3-4/week
3. Cargo 4	TWA	1 - 12'x7'x5' (14)			X	2-3/week
4. Cargo 5	American Airlines	1 - 14'x8'x5' (16) 1 - 6'x5'x5' (6)	X		X	2-3/week 6-7/week
5. Cargo 6	Pan American	1 - 14'x8'x5' (16)			X	2-3/week
6. Cargo 7	Delta Airlines	1 - 6'x5'x5' (6)	X			2-3/week
	Japan Airlines	2 - 5'x2'x3' (1)		X		3-4/day
	Qantas	2 - 22" diam x 36"		X		3-4/day
7. P. O. building	Airport Mail Facility	4 - 6'x3'x3' (2) 1 - 12'x7'x5' (14)	X		X	6-7/week 3-4/week
8. Flying Tiger hangar	Flying Tiger	1 - 12'x8'x5' (14)			X	1-2/week
9. Miscellaneous buildings	Wheeler Animal Shelter	1 - 5'x2'x3' (1)			X	1/week
	South Pacific Air Freight	Barrels		X		1-2/day
	WTC Air Freight	3 - 5'x2'x3' (1)		X		1-2/day
	Philippine Airlines	Barrels		X		1-2/day

Table 1 (continued)

Source and location	Tenant	Containers, number and size (cy)	Collection vehicle Front-end loader	 Back-end loader	 Pull-on truck	Collection frequency
Aircraft service centers:						
1. Hangars (service buildings)	American Airlines	3 - 6'x5'x5' (6)	X			6-7/week
	Airborne Freight	1 - 6'x5'x5' (6)	X			3-4/week
	Western Airlines	3 - 6'x5'x5' (6)	X			3-4/week
	TWA	5 - 6'x5'x5' (6)	X			6-7/week
	United Air Lines	1 - 32-cy compactor box			X	6-7/week
		5 - 6'x3'x3' (2)	X			6-7/week
		4 - 6'x4.5'x4.5' (5)	X			6-7/week
	PSA	2 - 6'x4.5'x4.5' (5)	X			6-7/week
	Air West	2 - 6'x5'x5' (6)	X			1-2/week
	North Western National Airlines	1 - 6'x5'x5' (6)	X			1/week
	Pan American	1 - 40-cy compactor box			X	3/week
	U.S. Coast Guard	1 - 12'x7'x5' (14)			X	2/week
	Butler Aviation	1 - 4'x2'x3' (1)		X		3-4/day
	Air California	2 - 5'x2'x3' (1)		X		1-2/day
2. Other stations	Shell Oil Depot	Barrels		X		1-2/day
	Standard Oil Satellite	Barrels		X		1-2/day
	S.F. Unified School District facility	Barrels		X		1-2/day
Aircraft maintenance base:						
1. United Air Lines Maintenance Base	United Air Lines	1 - 40-cy compactor box			X	6-7/week
		1 - 14'x8'x5' (16)			X	1/week

Table 2

COLLECTION VEHICLES AND INTERNAL ROUTING USED BY PRIVATE HAULER IN EXISTING SOLID WASTE SYSTEM, San Francisco International Airport July 1971

Type of vehicle	Collection route	Daily scheduled(1) collection time	Collection frequency	Approximate time for each internal collection, min
Back-end loader	Hilton → South Terminal → Piers → Garage → Central Terminal → Standard Oil → UAL Service → WTC Air Freight → Cargo 7	7:00 a.m. - 8:00 a.m., 11:00 a.m. - 1:00 p.m., 10:00 p.m. - 2:00 a.m., 4:00 a.m. - 6:00 a.m.	3 or 4/day	60 45 75 30
Front-end loader	Western → Air West → Post Office → PSA → Airborne → AA → Cargo 7 → UAL → Pier D and F → TWA	12:30 a.m. - 2:30 a.m.	1/day	150
Pull-on truck	Compactor box: PAN-AM UAL Service Center UAL Maintenance Base	7:00 a.m. - 8:00 a.m. 7:00 a.m. - 8:00 a.m. 7:00 a.m. - 8:00 a.m.	every other day	15
	Debris box: Delta, UAL (MB), AA, TWA FTL, U.S.C.G., others	irregular on call	every other day irregular	15 15

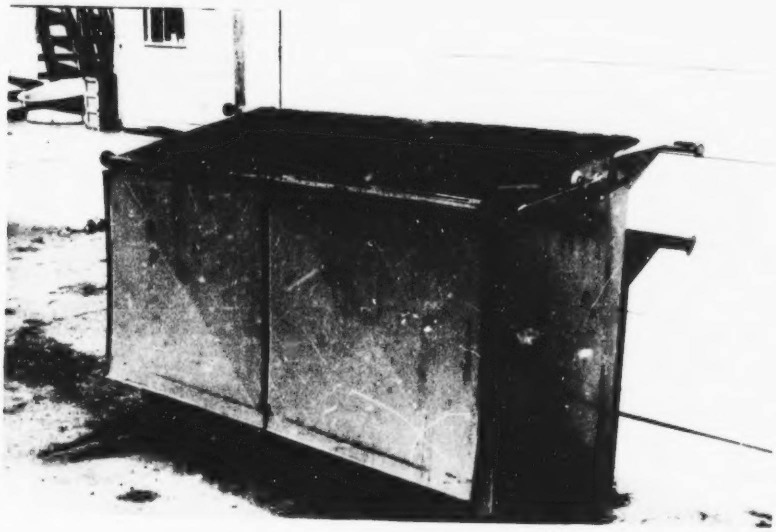
(1) The daily schedule is very flexible, with the actual collection time set at the convenience of the hauler.

hauler for storing the refuse after in-house handling and prior to truck collection. Containers vary in types and sizes, depending upon the tenant's need and the storage situation. The collection schedules and routes are described in Table 2. Additional details on collection in each of the four main airport areas are presented in the following paragraphs.

1. Passenger terminals. As seen from Table 1, the terminal complex includes a variety of tenants. The in-house handling of refuse is done by each tenant. The equipment used is normally of the janitorial type (brooms, waste baskets, miscellaneous containers, etc.). After in-house handling, the refuse is placed in the collection containers. In the passenger terminals, most of the wastes are deposited in three large refuse

rooms (two in the Central Terminal and one in the South Terminal) where wastes are stored for collection. In the Central Terminal rolling containers of approximately 1-cubic yard capacity are usually positioned in each room for storing refuse at the completion of in-house handling. A photograph of the container is shown on Figure 2. In the South Terminal refuse is thrown loose on the floor of the refuse room. A photograph of the refuse room is also shown on Figure 2. The hauler then shovels or throws the refuse into his collection truck. He collects from the terminal refuse rooms three or four times each day, and from other terminal areas as described in Table 2.

2. Air freight area. The in-house handling of freight and air mail wastes is done by each tenant. The containers and equipment used include standard janitorial containers plus special freight handling equipment for hauling the bulky packaging waste. All packing wastes do not remain at the airport for collection and disposal since the crating and uncrating of freight is normally done off the airport complex. Those wastes that are generated in the freight area result from additional crating or breakage. After in-house handling, refuse is stored for collection in front-end loading containers and debris



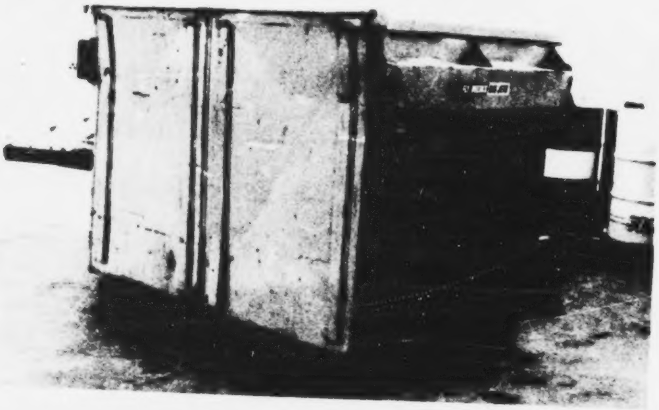
PORTABLE BACK-END LOADING CONTAINER

LOOSE-REFUSE ROOM

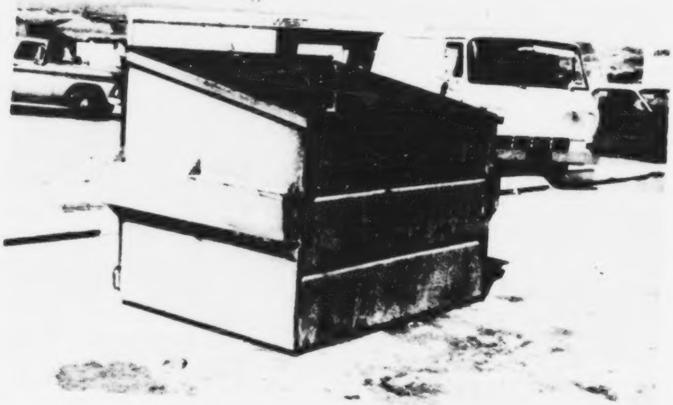
FIG. 2

REFUSE STORAGE CONTAINERS AT PASSENGER TERMINALS boxes. Photographs of the containers and debris box are shown on Figure 3. The bulky nature of the wastes requires containers with large volume capacities. The contents of these containers are hauled either to a transfer point or directly to the landfill.

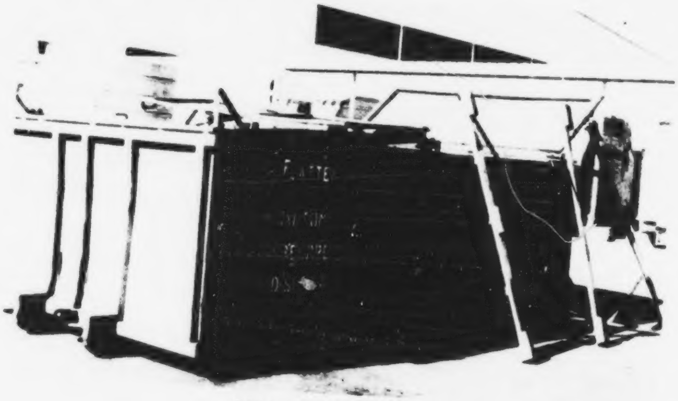
3. Aircraft service centers. Refuse from the service centers includes both hangar wastes and aircraft passenger wastes. In-house handling for hangar wastes is done by janitorial type service. In-house handling for aircraft passenger wastes is done in several different ways. The most significant of these involves wastes from flights serving meals. When the tenant has a flight kitchen at the airport, wastes from aircraft are taken to the service center. This in-house handling is done by tenant cleaning crews using special cleaning equipment, containers, and a truck. Refuse is taken from the aircraft, often in special portable containers (used to hold food and drinks at the originating airport, then to hold refuse as the food and drinks are used), and placed into a truck for delivery to the service center. Additional in-house handling at the service center includes hand separation of food wastes for grinding and disposal to the sewer at several locations, and paper and other wastes for delivery to a storage



PORTABLE FRONT-END LOADING CONTAINER



STATIONARY FRONT-END LOADING CONTAINER



PULL-ON DEBRIS BOX

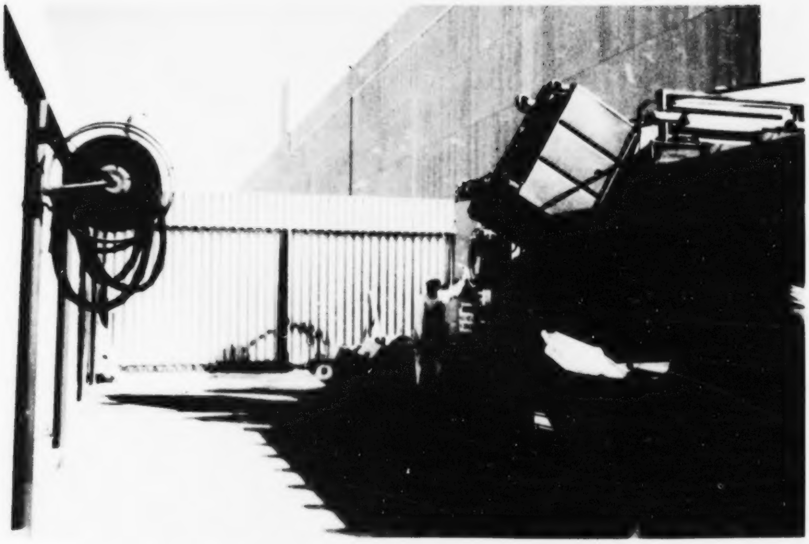
FIG. 3
REFUSE STORAGE CONTAINERS AT AIR FREIGHT AREA

container and collection by the private hauler. Those airlines without flight kitchens have catering services provided by off-airport caterers. The in-house handling of meal wastes for these airlines includes the caterer, since he removes meal wastes in the portable containers in which meals were delivered. In this instance, those wastes do not become a part of the airport wastes. However, a change in the supplier of flight meals could cause a significant increase in wastes to be handled. For these airlines, the internal aircraft cleanings (dirt, newspapers, etc.) are handled by cleaning crews. These cleaning wastes are normally taken by truck to the service center, although an airline with limited support facilities at the service center may dump such wastes into containers located at the terminal passenger loading piers.

After in-house handling, service center refuse is placed in front-end loading containers or stationary compactor containers for further collection. The contents of these containers are hauled directly to landfill, except when the tenant has provided a separate container to store salvageable metals. Several airlines have these special containers outside their hangars and sell the metals to scrap dealers.

4. Aircraft maintenance base. As noted previously, the single maintenance base at San Francisco International Airport is similar to an industrial complex. In-house refuse handling, therefore, involves more than normal janitorial service. Two full-time in-house collectors are employed to collect refuse in more than one hundred 2-cubic yard rolling containers using a small power tractor. The rolling containers are located throughout each plant department and are collected once a day during the day shift and moved to a 40-cubic yard stationary compactor for storage and collection. A photograph of the stationary compactor is shown on Figure 4. Some of the bulky and dense wastes are placed in an open 32-cubic yard debris box for storage and collection. These containers are hauled directly to sanitary landfill by the collector. Because this is an industrial complex, there are additional special in-house waste handling systems. Industrial sludges (oils, paint strippings, heavy metal coatings) are stored for periodic pumping and removal by the private hauler. Also, special salvage containers are used to store metals for a scrap dealer.

There are miscellaneous unorganized refuse collection activities not itemized above. Examples are demolition wastes and sewage sludge. As a part of the total waste handling



STATIONARY COMPACTOR WITH AUTOMATIC DUMPING DEVICE

FIG. 4

REFUSE STORAGE CONTAINERS AT AIRCRAFT MAINTENANCE BASE system their impact is small. Only when a major structure is demolished does the quantity of demolition waste become significant. It is then normally handled as a part of the construction contract with wood materials disposed of outside the airport and dirt, concrete, and broken asphalt used for fill material on the airport complex. Sewage sludge is normally processed as a part of wastewater treatment and is not included in this study of collection systems.

Solid Waste Handling Costs

The total solid waste handling costs should include the cost attributed to in-house handling, in addition to the fees paid to the private hauler. The cost of in-house handling for tenants at the airport was not available since the cost of janitorial service, which includes both building cleaning and refuse collection, is very difficult to split apart. Also, tenant records of maintenance crew activity often do not even identify the waste handling function. The collection and disposal costs, however, are available through the monthly bill from the private hauler. Each tenant was asked to provide, for the purposes of this study, his average monthly bill for refuse collection and disposal. The reported total cost for all airport tenants is approximately $20,000 per month. The unit collection cost, as quoted by the private hauler, is $4.00 per compacted cubic yard and $2.15 per loose cubic yard. This unit service cost varies with the account, depending upon the size of the account and the degree of difficulty in pickup.

Classification of Wastes by Source

A primary objective of this study was to develop information, in the form of predictive unit values, regarding refuse generation at the airport. To accomplish this, source and quantity data were developed from a weighing program and from a physical and chemical classification program. The results are summarized in the following subsections; the detailed procedures and data are presented in Appendix A.

Weighing Program

The weighing program was set up to determine both the total quantity of refuse generated within the entire airport complex and the portion of that total generated by each of the four major types of facilities within the airport previously described. In addition, a weighing of the wastes directly discharged from the aircraft was also conducted. The results of that weighing are included under the service center category.

To gain a meaningful result that represents existing solid waste practices, a one-week period was selected for the weighing of all the refuse generated at the airport. This weighing program was accomplished in the late summer of 1971 by a four-man team from the Engineering Department of San Francisco International Airport. The results are given in Table 3.

Table 3

SAMPLING DATA - SUMMARY OF QUANTITIES OF SOLID WASTES COLLECTED IN ONE WEEK
San Francisco International Airport, July 1971
Tons

Source \ Day of week(1)	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Total
Passenger terminals(2)	9.0	10.5	9.9	13.7	7.8	9.1	8.7	68.7
Air freight area	5.1	3.5	3.3	3.4	4.8	5.2	4.5	29.8
Aircraft service centers(3)	29.8	15.5	23.0	13.6	14.6	15.7	21.0	133.2
Aircraft maintenance base	15.8	7.7	7.8	7.8	7.8	--(4)	8.7	55.6
Total	59.7	37.2	44.0	38.5	35.0	30.0	42.9	287.3

(1) Defined as 7:00 a.m. from the day shown to 7:00 a.m. of the following day.

(2) Includes wastes from passenger aircraft that are discharged to the containers around the piers, but excludes wastes from Hilton Hotel.

(3) Includes wastes from passenger aircraft that are discharged to the containers located at the service center.

(4) No waste is hauled on Saturday.

The daily total amounts varied from 30.0 tons on Saturday to 59.7 tons on Monday. The total refuse generation from all San Francisco International Airport activities in one week was 287.3 tons. This figure excludes the wastes from the Hilton Hotel, which is located on the airport premises, because hotel service was not considered a normal part of airport activities. The largest quantity of waste comes from the aircraft service centers, as most aircraft wastes are handled through this point. In those few cases where aircraft wastes are discharged to containers around the terminal piers, the quantities were included as a part of the passenger terminal wastes.

Since the weekly generation datum was to be used in establishing average annual refuse generation figures for the airport, it was necessary to examine the change in generation caused by a busy holiday weekday. This special weighing program was conducted on Labor Day in September 1971. The results showed that the one-day refuse generation was 35.1 tons subdivided as follows: passenger terminals, 11.2 tons; air freight service area, 8.5 tons; aircraft service centers, 7.3 tons; and maintenance base, 8.1 tons. These data indicate that the refuse generation on a holiday does not differ greatly from a normal weekday. The reason might be the balancing effect of work activity at the different refuse sources on holidays. The increase of passengers and the accumulation of mail and cargo tend to increase the wastes at the terminal and cargo areas, whereas the slowdown of work at service centers and the maintenance base tend to decrease the wastes at those areas.

The total weight of refuse generated in one week is believed to be an average value that can be used for projecting future waste quantities. To be useful in projections, each source (as shown in Table 3) should have a unit of waste generation identified that is directly related to the quantity of waste from that source. Examples would be number of passengers, number of flights, or square feet of floor space in service centers; number of flights or cargo tonnage in air freight service; and number of aircraft, number of employees, or square feet of space in maintenance bases. The units considered most representative and the unit generation of solid wastes for each source are:

- 0.53 pound per passenger for the terminals,
- 7.10 pounds per ton of cargo for the air freight area,
- 1.02 pounds per passenger for the service centers, and
- 2.19 pounds per employee per day for the aircraft maintenance base.

As mentioned, the weighing of wastes discharged directly from aircraft was done through a separate measuring program. A summary of these weights, along with flight information, is shown in Table 4. The quantity of wastes from aircraft was proportional to the number of meals served, the types of meals served, and the total flight time. Unit quantity values ranged from 0.18 pound per passenger to 3.76 pounds per passenger. The average weight of wastes was 2.51 pounds per passenger for meal service flights where meal wastes were discharged at the airport. The weight of wastes per passenger where flight meal wastes were removed from the airport complex by caterers and where no meals were offered on the flight was 0.54 pound per passenger. These per passenger figures are used in Chapter 6 for the projection of solid waste generation

Table 4

SAMPLING DATA - QUANTITIES OF SOLID WASTES DISCHARGED PER PASSENGER, San Francisco International Airport July 1971

Destination	Total flying time	Meals served(1)	Number of stops	Total solid wastes discharged, lb	Number of passengers	Solid wastes discharged per passenger, lb
I. Passenger aircraft wastes						
Salt Lake - San Francisco	1 hr 33 min.	B	0	82.1	48	1.71
	1 hr 33 min.	B	0	52.1	36	1.79
Portland - San Francisco	1 hr 33 min.	B	0	68.0	46	1.47
	1 hr 33 min.	B	0	72.1	29	2.48
Omaha - San Francisco	3 hr 20 min.	B	0	53.2	31	1.72
Honolulu - San Francisco	4 hr 50 min.	SB/B	0	219.0	83	2.64
	4 hr 50 min.	SB/B	0	236.2	88	2.69
New York - San Francisco	6 hr 5 min.	D	0	349.0	101	3.46
Tokyo - San Francisco	13 hr 0 min.	D/SB/B	0	325.6	96	3.40
	13 hr 0 min.	D/SB/B	0	465.0	124	3.76
Average						2.51
II. Passenger aircraft wastes excluding meal service wastes(2)						
Los Angeles - San Francisco	1 hr 3 min.	none	0	68.1	73	0.86
	1 hr 3 min.	none	0	30.6	40	0.77
Long Beach - San Francisco	1 hr 5 min.	none	0	17.0	48	0.35
Las Vegas - San Francisco	1 hr 13 min.	B	0	8.0	31	0.26
Salt Lake - San Francisco	1 hr 33 min.	none	0	14.5	82	0.18
Seattle - San Francisco	1 hr 38 min.	B	0	24.5	82	0.30
Vancouver - San Francisco	1 hr 59 min.	D	0	20.0	21	0.95
Kansas City - San Francisco	3 hr 18 min.	B	0	25.0	48	0.52
Washington, D.C. - San Francisco	5 hr 22 min.	L	0	24.0	23	1.04
Pittsburgh - San Francisco	6 hr 16 min.	B	1	28.7	88	0.33
Cincinnati - San Francisco	6 hr 16 min.	B/SB	2	25.6	66	0.39
Average						0.54

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(1) B, L, D, and SB represent breakfast, lunch, dinner, and snack, respectively.

(2) The meal service wastes, which are normally separated at the cleaning service, were not included in the samples. The wastes included were sweepings, paper towels, etc.

for those areas where wastes are considered to vary with the number of passengers.

For the interpretation of the unit quantity values presented here, it should be noted that separate and different passenger loading data were used to derive the terminal and service center values from those used to derive the aircraft values. In deriving the terminal and service centers' values, total annual refuse quantities were divided by total annual passenger loadings. The passenger aircraft values were derived by dividing the quantity of refuse from each aircraft by the number of passengers on that flight.

Physical and Chemical Characteristics

As a first step in determining waste characteristics, a review of the physical and chemical testing methods available for airport solid wastes was completed. By observation it was noted that most of the airport wastes were paper and corrugated paper boxboard, plastic products, food wastes, and wood pallets. The following nine categories were selected for the classification of airport wastes:

1. Paper and paper products
2. Plastics
3. Food wastes
4. Wood and wood products

5. Trimmings
6. Metal and cans
7. Glass, stone, and ceramics
8. Dirt and demolition materials
9. Miscellaneous wastes, such as rubber, rags, and leather, etc.

The development of refuse characteristics was aimed at these categories to provide basic data for the selection of waste handling, processing, and recycling methods.

The sampling technique for physical composition followed APWA (American Public Works Association) standard procedures. Wastes from the four main airport sections were sampled and subjected to statistical analysis. The summary result is shown in Table 5. The percentages of refuse components shown reflect clearly the types of areas from which the refuse is generated. The passenger terminals generate a large quantity of paper wastes; the air freight area discharges mostly bulky cardboard boxes and wood pallets; the aircraft service centers throw away a lot of waste foods and metal cans; and the maintenance base combines all types of wastes and shows the characteristics of an industrial complex.

The organic portion of all refuse samples from all sources was subjected to shredding and subsequent chemical analysis. Moisture content and volatile solids and ash tests were conducted. These two tests provide information on the chemical and physical nature of refuse that may be needed for selecting

Table 5

SAMPLING DATA - SOLID WASTE COMPONENTS BY SOURCE
San Francisco International Airport, July-November 1971
Percent in weight (mean values)

Source Component	Passenger terminals	Air freight area	Aircraft service centers	Aircraft maintenance base
Paper & paper products	70.6	45.7	32.1	50.9
Plastics	5.3	10.0	10.3	9.5
Food wastes	5.3	3.2	33.6	14.9
Wood & wood products	3.3	17.1	2.5	5.0
Trimmings	0.2	2.6	0	0
Metal & cans	6.1	7.7	11.9	5.8
Glass, stone, & ceramics	4.1	3.3	4.0	9.6
Dirt & demolition materials	1.8	4.4	0.9	0.9
Miscellaneous	3.3	6.0	4.7	3.4
Total	100.0	100.0	100.0	100.0

Table 6

SAMPLING DATA - CHEMICAL CHARACTERISTICS OF ORGANIC SOLID WASTES BY SOURCE
San Francisco International Airport, July-November 1971
Percent (mean values)

Source Content	Passenger terminals	Air freight area	Aircraft service centers	Aircraft maintenance base
Moisture	25.4	20.5	28.5	16.5
Volatile solids	90.9	89.5	91.9	93.6
Ash	9.1	10.5	8.1	6.4

waste processing methods. Results of the analyses are shown in Table 6. The average moisture content ranged from 16.5 to 28.5 percent by weight; volatile solids, from 89.5 to 93.6 percent; and ash from 6.4 to 10.5 percent. It is important to note that these percentages were of total organics and not of total sampled refuse, since the inorganic materials were separated prior to shredding and testing.

Survey of Other Airports

Purpose and Scope

As mentioned in Chapter 1, a survey of other airports was conducted as a part of this study in an attempt to determine what types of solid waste systems and management methods are used throughout the country. The following criteria were used in selecting the airports.

- Airport location (wide geographic distribution desirable).
- Capacity of passenger service (larger facilities preferred).
- Volume of air freight (large volume preferred).
- Types of aircraft served (wide variety preferred, both domestic and international flights).
- Physical layout of the airport (both spread-out and concentrated layouts desirable).

It was hoped that the data gathered from the survey would help to establish the general validity of refuse generation parameters set by sampling at San Francisco International Airport. For example, if another airport wishes to use the San Francisco refuse parameter of pounds per passenger per day in selecting equipment, it would be important to know if the quantity measured at San Francisco was similar to the quantity that must be handled at another airport.

The survey was conducted by mailing questionnaires to selected airports, and then by conducting personal interviews with management personnel at certain airports that received the questionnaire. A sample of the questionnaire is included in Appendix B. The questionnaires were mailed to 46 airports, and responses were received from 36. Interviews were held at 8. A compilation of selected data contained in the returned questionnaires is included in Table 7. A brief interpretation of that information is presented in the following subsections.

Solid Waste Systems

The most widely used storage container is the 2- to 6-cubic yard front-loading equipment. Of airports responding, 67 percent used this type of container. Generally, the larger and more efficient containers are used at the larger airports. Some large airports may use every container size, from 1-cubic yard through 30-cubic yard compactors.

Transfer of refuse to increase the efficiency of transportation to the disposal site is practiced at 14 percent of

Table 7

SELECTED RESULTS FROM NATIONAL AIRPORT SURVEY, NOVEMBER 1971

Total number of airports responding: 36

Item	Number of airports	Percent of total
Solid Waste Systems		
1. Types of storage containers used		
Less than 1 cy	10	28
1 to 4 cy rear loading	16	44
2 to 6 cy front loading	24	67
10 to 20 cy pull-on debris boxes	11	31
Larger than 30 cy compactor	11	31
Open storage requiring shoveling	1	3
2. Transfer	5	14
3. Recycling	1	3
4. Waste discharge point used for aircraft		
Service center hangar	4	11
Containers at piers	26	72
Terminal refuse rooms	4	11
Containers at the terminal	1	3
Centrally located compactors	2	6
Management Methods		
1. Types of agencies collecting solid wastes		
Private	21	58
Public	1	3
Airport	2	6
Combined (public or airport and private)	12	33
2. Types of contractual arrangements		
Each tenant does all contract negotiation without assistance from the airport authority	22	61
Each tenant does all contract negotiation with rate control by the airport authority	1	3
Combination of above	1	3
Airport authority represents all tenants with no exclusions	3	8
Airport authority represents all tenants but tenant may elect to be excluded	6	17
3. Solid waste collection activity interference with aircraft operations		
Frequently	0	0
Occasional	1	3
Seldom	11	30
Never	24	67
4. Up-to-date solid waste planning		
Yes	7	19
No	29	81

the airports. This figure is expected to increase in the future as disposal sites become more limited and remote.

Processing and recovery of refuse is becoming a more significant aspect of planning for solid waste systems. Several airports presently have tenants who have installed incinerators or wet pulping units to improve the efficiency of refuse collection and transport. However, the high capital cost of processing equipment has limited its use in an airport complex where the total quantity of waste has been small. Only the Sacramento Metropolitan Airport now practices recycling, and there only cardboard is recovered. In addition to high capital cost, a further deterrent to processing and recovery is the lack of nearby markets for the recovered materials.

Because of the significant quantities of refuse generated on aircraft, each airport was asked at what point this material was collected and in what type of container. An efficient application of equipment at one airport might be adapted to others. It is indicated in Table 7 that 72 percent of the airports discharge aircraft wastes to containers located at the loading piers. Although this is the most commonly reported container location for all airports, the authorities contacted during the personal visits expressed concern that solid waste handling in this location may conflict with the increasing number of aircraft movements. Also, the importance of security in aircraft movement areas is now becoming more widely recognized, thereby limiting the freedom of vehicle movement.

Management Methods

Data on the management of solid waste systems were gathered from the questionnaire in an attempt to identify any significant trends or successful modifications of methods commonly used on an airport complex. A majority (58 percent) of the airports are served exclusively by private haulers. The next largest group (33 percent) is a combined management of private haulers (usually serving each individual tenant) and public or airport haulers (usually serving the terminal area). Each tenant handles his own contract arrangements with the private hauler in 61 percent of the airports, while 31 percent of the remaining airport authorities exercise some amount of control in arrangements with the private haulers. Each method of contracting seems acceptable since interference with aircraft operations is reported as practically nonexistent in 97 percent of the airports.

Airport personnel were also asked if any up-to-date planning for solid waste systems was being done. The greatest number (81 percent) responded that no planning had been done or was now underway. Although individual tenants or private haulers might have underway or completed planning studies unknown to the airport officials, the widespread existence of such studies is not expected.

Adequacy of the Existing System

Before ending a discussion of the present conditions of solid waste systems both at San Francisco International Airport and at other airports around the country, it is worthwhile to comment on the adequacy of existing systems. The primary function of the system is to collect and remove refuse efficiently and with limited effect on the environment. Is this now being done, and if not, what is the potential for its being done in the future?

Existing solid waste systems are effectively collecting and removing materials within most airport complexes. The detailed review of the existing San Francisco International Airport system revealed that it includes most of the more practical and efficient containers and trucks available. Environmental problems are minimal. One problem is that of blowing papers at the piers in the terminal area, which normally occurs under a high wind condition when front-loading containers are emptied. A second environmental problem is caused in the areas where stationary compactors are used. Because the refuse thrown in compactor containers often is wet garbage, a leachate develops at the interface of the compactor and container. This leachate is presently collected and routed to the sanitary sewer at only one of the three compactor installations on the airport. Although the San Francisco International Airport treats all storm drainage waters and therefore does not discharge leachate directly to San Francisco Bay, airports should require that leachates be discharged to a sanitary sewer for subsequent treatment.

The solid waste management method at San Francisco International Airport is adequate in most areas of the complex. The terminal buildings are the greatest problem. Access to the existing refuse rooms is difficult by collection truck, and because of the container size used there, the hauler must make three to four trips per day to collect wastes. This is inefficient. The number of collection trips and costs could be greatly reduced by increasing container size and using more compactors.

Chapter 4

POTENTIAL MANAGEMENT METHODS

Introduction

The management of solid wastes is growing more complex as airports become larger and waste quantities become greater. With increasing costs, more attention should be given to coordinated management in an attempt to improve the efficiency of solid waste systems. Alternative management methods should be considered in an attempt to develop the most efficient combination of collection, transport, and disposal of solid waste.

In this chapter, potential management methods are described. Potential solid waste systems are described in Chapter 5.

Types of Management Methods

After a review of airport operations (including those at San Francisco and other visited airports), three primary management methods were identified and selected for evaluation.

Method 1

The airport authority maintains full operational control over the entire refuse handling function (collection, transport, and disposal). All equipment is the property of the authority, and tenants are billed for the service provided. The characteristics of this system are as follows:

a. The airport authority makes a final decision on the solid waste system activities that are acceptable for the total airport complex.

b. Prices for refuse service for all tenants are set by a single authority.

c. Capital and operational costs for the system are borne by the authority and paid for by the user charge.

Under this method, the airport authority plays a major role in providing refuse service to its tenants. This is a function that public agencies do not now normally undertake for commercial and industrial entities.

Method 2

The airport authority shares management with the tenants. The sharing can take place in many ways, ranging all the way from complete control (nonoperational) of management by the airport to 99 percent control by the tenants. Primary characteristics of this method are as follows:

a. The airport authority, acting as the control agency for the tenants, awards a franchise on a competitively bid basis for refuse collection and disposal.

b. Within limits, each tenant selects the collection system best suited to his needs.

c. Capital and operational costs are incurred by private industry.

Under this method, the airport authority is directly involved in evaluating refuse systems as to environmental effects and economies, but relies on private industry to provide refuse service.

Method 3

The airport authority leaves all management, including refuse collection and disposal functions, in the control of each tenant, maintaining only an enforcement control over tenants to the extent of safeguarding aircraft movement, the environment, and public health. The characteristics of this system are as follows.

a. Each tenant provides for refuse removal activities independent of the airport authority, either through contract with a private hauler or by using his own system.

b. The function of the airport authority is only regulatory, thereby diluting the potential for recognizing and installing refuse systems that would benefit the airport complex and the environment.

Under this method, the airport authority plays a minor role in selecting new refuse systems or improving existing systems. Each tenant evaluates his system, and any modifications to that system are accomplished on an individual cost-benefit analysis.

Important Planning Considerations

Before making a final decision on the selection of a management method, the airport authority should recognize the important considerations involved. These concern implementation, operations and environment, and finances.

Implementation

Implementation involves organizing all of the elements of a selected management method so that operations can begin. The most important consideration here usually relates to providing the transition from an existing method to a new or modified method. In the case of a new or modified method, the transition may be extremely difficult. An example would be changing from private hauler contracts with each tenant to a negotiated contract between the airport and the hauler. A change from any of the existing methods to a new one may require extensive capital investment, financing, and changes to existing operational procedures.

Management Methods 1 and 2 show the greatest internal implementation potential because a strong public agency, the airport authority, can act directly to improve collection efficiency for the entire airport complex. Under Method 3, the individual tenant may have difficulty implementing a method of areawide benefit within his specific lease area. Careful method selection is necessary if the implementation problems are to be overcome.

Operations and Environment

Operational requirements for the airport would vary significantly according to the method selected. Under Method 1, full operational control, the airport needs the men and equipment to accomplish daily refuse collection and hauling. The arrangements for disposal would also have to be handled by the airport. Vehicle maintenance facilities and storage buildings would be operated by airport personnel. In contrast, Methods 2 and 3 would not require the operation of any part of the collection, transport, and disposal system by the airport.

Total effect upon the airport environment is a primary concern in assessing the advantages of each method. Method 1 offers the best opportunity for public control of environmental effect. An airport complex is a highly developed commercial area that is exposed to constant public scrutiny in heavily traveled sections such as the terminal, a fact often overlooked under Management Methods 2 and 3. Management under these methods often considers only individual tenant development of cost-benefit without regard for areawide environmental effects.

Finances

The capital required to purchase, install, and operate a solid waste collection system is an important consideration in selecting a management method. The initial capital outlay may be a large amount. Funding such amounts is included under finances, along with an evaluation of interest rates, billing methods, and bond alternatives.

The control of financing varies with the different management methods. Under Method 1, the airport authority must set the financing program. The sources of funds are general obligation bonds and revenue bonds. Each tenant would be billed for service at a level to pay back the bonds, cover operational expenses, and meet administration costs. Under Methods 2 and 3, financing would be done by each tenant, either through direct capital investment at prevailing interest rates or by paying a private hauler a service fee which covers capital, operating, and administrative costs. In assessing the impact of financing on the desirability of each method, it should be noted that private industry can obtain capital much faster than a public agency if immediate changes are needed. However, private capital is usually more expensive than that acquired through public bonds, thereby increasing the long-term cost of the system.

Chapter 5

POTENTIAL COLLECTION AND HANDLING METHODS

Introduction

Before proceeding with the evaluation of alternatives and selection of a recommended system, it is important to consider the general characteristics of steps in the handling of refuse from point of generation through disposal. As set by the scope of work for this study, the only step to be evaluated was collection (including in-house handling). However, subsequent transport, transfer, and processing are an integral part of refuse handling and must be considered when evaluating collection. An evaluation of the existing methods and of modifications or more efficient combinations of them is presented in subsequent sections of this chapter.

The in-house handling step is difficult to remove from individual tenant control (a no-control condition for the airport) and therefore is not evaluated here.

Compaction is discussed as a separate process, although it can be used as a part of transfer stations or within collection vehicles.

Collection

The aspects of collection that must be analyzed are size, type, and location of refuse containers, frequency of collection,

collection routes, type and size of collection vehicles, and size of crew. Typical unit costs for collection range from $8 to $25 per ton.

Containers

The alternatives for refuse containers at the individual pickup points include the following: metal or plastic barrels (usually 32-gallon size); enclosed metal boxes, either wheel mounted (usually 2- to 10-cubic yard) or stationary (usually 2- to 6-cubic yard), that may be emptied into a collection truck or may be hauled individually to the disposal site; larger debris boxes (usually 10- to 30-cubic yard) that are pulled onto a tilt-frame truck bed for delivery to the disposal site; and large compaction-type metal boxes (10- to 40-cubic yard) that are either pulled onto a tilt-frame truck bed or are complete trailers in themselves.

The selection of container type is determined largely by the collection equipment utilized; discussions of this are included within the subsections entitled "Collection Routes" and "Collection Vehicles." The container size is dependent upon quantities and types of refuse generated and upon frequency of collection; further details are given in the following subsection. The location of refuse containers is determined by convenience to those generating the wastes, by convenience to those collecting the wastes, and by general overall appearances.

In commercial and industrial areas such as the airport, the pickup point for refuse is usually established to suit the operations and convenience of the tenant. In most industrial areas and in well planned commercial areas, this location is also suitable for the collector, but in areas with poor vehicular access the location may result in added time and expense for collection.

Frequency of Collection

The frequency of collection is related to the rate at which the wastes are generated, the size of the container in which they are stored, and the potential health hazard they may represent. Collection from such mass wet-garbage producing sources as restaurants and flight food kitchens should be at least once a day for proper health protection.

Non-food wastes (from commercial and industrial areas) create no health problems and thus may be collected as generation rates dictate. In some areas, this may be several times in one day; in others, it may be once every two weeks or even longer. Collection may be either on a regularly scheduled basis or an on-call basis; both are used by the tenants at the airport. It is important, however, that collection be frequent enough to prevent the wastes from ever becoming a visual nuisance.

There must be a balance between size of container and frequency of collection. In wet-garbage producing areas, frequency of collection is dictated by health considerations, and the required container size is automatically determined by the volume required to contain the maximum amount of refuse generated in the interval between regular pickups. In other areas, there is an economic balance between size of containers and frequency of collection. Too small a container would require too frequent collection. An oversized container, on the other hand, might never be filled within a reasonable period and thus would require extra time and effort for handling a large unit to collect a small amount of wastes. In areas exhibiting uniform conditions, the balance between container size and collection frequency can be theoretically derived. For most conditions, however, a knowledge of the collection system and visual observation of container contents are sufficient for recommending changes in container size and number or in collection frequency. At present, the private hauler and each tenant work out the proper balance independently of other tenants.

Collection Routes

Efficiency of vehicular movement dictates that a collection route should be in as compact a geographic area as possible. Accordingly, containers within a given area should be as standardized as possible to allow uniform service from a single collection vehicle. Different types of containers require different types of collection vehicles, and it can be highly inefficient to have several collection routes through the same area just to service different types of containers. Some differences in container types will be required to serve the different sources of wastes properly, but the variety should be kept to a minimum. Since different types of containers are actually needed in a given system, it is probable that they will require different frequencies of collection, which will necessitate separate collection routes anyway.

The number of stops along a collection route is set by the number that can reasonably be accomplished in a working day. This will vary with type of in-house handling, size of collection crew, type of collection vehicle, vehicular access, distance between pickup points, terrain, haul distance to transfer station or disposal site, and weather.

Collection Vehicles

There are several types of collection vehicles, and some types are available in several sizes. Many of the vehicles are designed to coordinate with only one type of container, so flexibility becomes a problem in selecting solid waste equipment. The more common types of vehicles in use today are described in the following paragraphs. Most of these are used by the private hauler who serves San Francisco International Airport.

One common type of vehicle-container system is the self-loading front-end compaction system. Truck capacities usually range from 20 to 35 cubic yards. Individual containers are lifted over the truck cab (using the truck hydraulic system), and dumped into a top opening immediately behind the cab. After the dumping cycle is completed, the contents of the truck are compacted by means of a hydraulically operated blade that achieves a volume reduction of about 4 to 1. A one-man crew is used, and that man need never exit from the cab of his truck to perform the collection duties along his route. The front-end loader may also be obtained as a noncompaction unit. In balancing the cost of a compaction unit against that of the noncompaction unit, the extra load-carrying capabilities of the compaction unit must be considered. Typical unit costs range from $9.00 to $12.00 per ton, depending on haul distance to the landfill.

A second type of vehicle-container system is the back-end loader. Truck capacities usually range from 15 to 26 cubic yards. The usual containers for this system are 32- to 50-gallon metal or plastic barrels, although somewhat larger units may also be used. A wheeled container (usually 1- to 2-cubic yard capacity) is available that can be emptied into a back-end loader using the hydraulic system of the truck. Because of the relatively small size of all the containers, the back-end loading system is ordinarily used only within residential areas. However, space for larger commercial type containers is limited in some areas of the airport, so small containers have been used and may be needed in the future. Crews of one to three men (including the driver) may be used on back-end loaders. The refuse is partially compacted by a hydraulic compaction blade that achieves about 3 to 1 volume reduction. In deciding on the use of a back-end loader, the flexibility it offers for loading loose refuse by hand often is an important factor. Typical unit costs for back-end loader systems range from $13.00 to $19.00 per ton, depending on haul distance to the landfill.

A third type of vehicle-container system is a tilt-frame truck and debris box. The large metal debris boxes are stationed in areas that produce large volumes or bulky types of refuse. When full, the boxes are pulled onto the trucks and taken to the disposal site for emptying. One-man crews are used. In areas where large volumes of readily compactible refuse (e.g., a maintenance or terminal area) are produced, a self-compaction debris box may be used. In evaluating the use of this equipment, the combination of in-house handling methods and debris box location is important. The larger the debris box, the larger is the area that may be served and the more extensive must be the in-house handling that delivers the refuse to the box. Typical unit costs range from $6.00 to $17.50, depending on whether or not contents are compacted and on distance to the landfill.

Crew Size

The significant increase in labor costs over recent years has had the same effect in refuse collection as in other fields: an emphasis on increasing automation and decreasing manpower. Accordingly, the trend in development of refuse collection equipment has been away from the traditional back-end loaders with multi-man crews toward systems using one-man crews.

As indicated in the preceding subsection, the only major equipment in use today with multi-man crews is the back-end loader. In choosing the optimum size for a refuse collection crew, one must consider an economic balance between the efficiency gained by having several men load a truck and the labor time lost by having those same men sit idle while they ride to the disposal site and back.

Transport

Transport is defined here as the moving of refuse from a collection point to another area for additional processing or disposal. Considerations in selecting a means of transport include the following:

1. The wastes should be moved efficiently and economically from one area to another.
2. The wastes should be fully contained to prevent dust, litter, and possible health hazard.

The transport methods available for use at the airport include pipeline and vehicles. Vehicle (truck) transport is presently used by the private hauler to remove refuse from the airport complex to a disposal site. Both pipeline and vehicle transport systems are discussed in this section.

Pipelines

Pulping and Wet Transport. The pumping of a slurry of refuse and water through a pipeline from in-house processing to a collection point is defined as wet transport. Transporting refuse in this way is normally done for only short distances and within a limited number of buildings. At San Francisco International Airport, the candidate areas for installing such a system are the terminal complex and the aircraft maintenance base. In-house processing is normally done by a grinding or pulping device similar to a home garbage disposal unit. These devices are larger than home grinders, ranging in size from 5 to 40 horsepower. After grinding, the slurry either flows by gravity or is pumped to the collection point where an extractor removes the water, and the remaining solid material is placed in a container for subsequent processing. As described here, wet transport is not a complete transport system because additional vehicle transport is normally necessary to deliver the solid waste to a disposal site.

The wet transport system is usable at the airport only as an in-house handling system, and has been included in this discussion only because its beneficial effects extend beyond the in-house system. The unit cost of the wet pulping and transport system would range from $1.50 to $6.60 per ton under normal conditions.

Dry Vacuum Transport. Within the past 10 years, a new method of pipeline transport of solid wastes has been introduced. This transport system moves dry unprocessed domestic refuse (no bulky items) by air-stream from individual collection points to a central processing, transfer, or disposal station. The system is still in the development stage, but problems are being worked out on a large (30-ton per day) system completed in 1971 at Disney World in Florida. That system size is comparable to the present 287.3 tons per week (40 tons per day) of refuse generated at San Francisco International Airport.

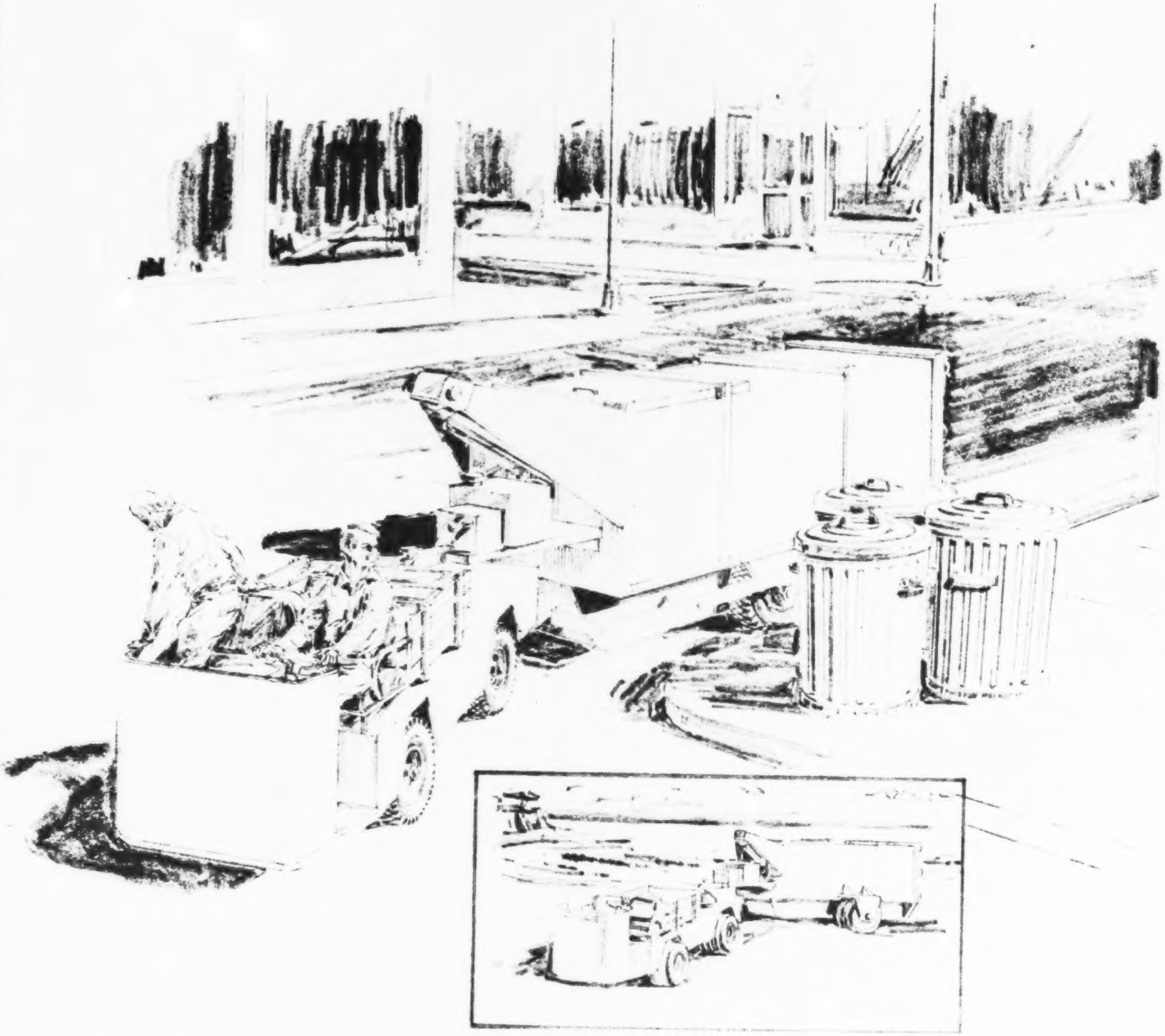
A dry vacuum transport system might serve the entire airport complex. However, an areawide installation would require extensive excavations in existing paved areas for a large-diameter buried pipeline (12 to 20 inches), and thus may not be feasible. Construction costs under these conditions would be higher than normally expected. The unit cost of the dry vacuum transport system would exceed $10.00 per ton, depending on the size of the collection area.

Vehicles

Trucks. Transport of refuse in trucks has been the traditional method of moving waste materials after collection. Often, the same truck is used for both collection and transport, but refuse may be transferred from small trucks to larger trucks for subsequent transport.

The unit costs for a transport system using transfer trailers are dependent upon labor costs and vehicle maintenance costs. The range is from $0.08 to $0.13 per ton per mile. Transport costs within an airport complex are low because the longest haul distance without leaving airport boundaries will normally be from 1 to 2 miles. Internal transport costs in this case are included with collection costs.

Other Vehicles. Vehicles other than trucks can be used within an airport where the standard refuse truck is too large to serve an area with limited space or where it would interfere with aircraft operations on the parking apron. Since size is the most critical factor in those cases, smaller vehicles are normally used. One example is the powered towing tractor used to pull baggage carts. In a refuse movement application, a tractor could serve the aircraft passenger loading piers by towing rolling refuse containers from generation points within operational areas to a collection or loading area outside operational areas for transfer to a larger vehicle. A conceptual drawing of typical equipment is shown on Figure 5.



SOURCE: AMS CO., FRESNO, CALIF.

FIG. 5

TYPICAL COMPACTION TRAILER AND TRACTOR

The unit costs for transport vehicles of this type are based on equipment and operator costs. Full utilization is important to obtain a low unit cost because a single towing vehicle and operator has the capacity to serve many rolling cans. Since this is an internal transport system (total mileage of transport is low), the unit cost is expressed on a per ton basis, not per ton per mile. This cost ranges from $2.00 to $3.60 per ton as estimated for San Francisco International Airport.

Processing

Processing methods that have been developed and that are important to collection and transport include compaction, shredding, separation, and high-compression baling. These processes are discussed in the following subsections. Additionally, incineration is important to the airport collection system when it is used as a volume reduction process by individual sources of refuse (tenants). Of the processes, only compaction (in collection vehicles and containers) is presently used in the airport's system.

Compaction

The process of compaction is used most effectively in conjunction with transfer stations. The purpose is to reduce the number of transport vehicles by consolidating the loads.

There is, however, a practical limit to the amount of compaction that may be attained. If the loads are too tightly packed, unloading becomes problematic. In addition, over-compaction may produce load weights in excess of the vehicle's tolerance or in excess of highway load limits. Compaction may be achieved either in a loading chute at the transfer station or in the transport vehicle itself. The cost of compaction is minimal and adds only $0.10 to $0.20 per ton to the total annual costs of transfer.

Shredding

A shredder is used to reduce solid wastes to a uniform size. Examples of shredding equipment are shears, pulpers, and different types of mills. Recently developed shredders are designed to process all types of heterogeneous refuse without the necessity for pre-separation of heavy or bulky items.

A shredder can be used in combination with other processes. Until recently, shredding was considered only as a preparation of solid wastes for immediate disposal, but now it has proven to be a beneficial first step to other processing methods. Examples of this are included in research now underway on separation and incineration at Menlo Park, California, and high-compression baling at San Diego.

Shredding costs are dependent upon the processing sequence in which a shredder is used. As a separate process, total annual costs for shredding would be approximately $5.00 per ton of refuse processed.

Separation

The process of segregating solid wastes into individual components is known as separation. It is used in combination with other processes, usually to aid in the recovery of specific materials. The separation can be accomplished by a variety of methods: hand picking, magnetic separation, vibrating screens, flotation, and air classification. Hand picking is the most commonly used method, but its efficiency is very low. All other methods require size-reduction processing (shredding) prior to separation.

The operating costs ($0.50 - $14.00 per ton) for separation are usually included in a combined processing cost with shredding, incineration, or disposal.

High-Compression Baling

High-compression baling is a process that produces high-density refuse bales. The range in density is from 50 to 70 pounds per cubic foot. At such densities, the volume is reported to be only 20 percent of the volume taken up by the same refuse in an uncompacted state. The use of high-compression baling for solid wastes is a recent development, and data from full-scale operations are not yet available in sufficient quantities for complete evaluation. As might be expected, the bales are economically advantageous in long-distance transportation of refuse. They also have advantages in sanitary landfills, although the condition of the bales after an extended time period in a landfill has not been fully established. Research in disposal of baled refuse in an ocean environment is presently being conducted as a part of airport expansion in Hawaii.

The total annual costs for baling are expected to range between $3 and $5 per ton of refuse processed. The costs will vary with the type of auxiliary equipment that may be used to seal the bales before disposal.

Incineration

Incineration is a means of processing a large volume of solid wastes under controlled burning conditions to produce for disposal a much smaller volume of inert ash and residue. The particulate and gas emissions from modern installations are controlled by particulate removal equipment and by additional combustion chambers. Incineration is not usually preceded by any other processing, although shredding of refuse is proving advantageous for better combustion, and the separation and removal of selected noncombustibles prior to incineration also improves combustion. Recent developments in incineration include the addition of electrostatic precipitators for particulate removal and the addition of heat energy conversion systems to provide steam or to generate electricity.

Incineration of solid wastes must be evaluated in connection with final disposal of the residue. It is an excellent method of reducing solid waste volume but does require skilled operators.

Total annual costs for incineration are dependent upon the type of furnace installed and the method of particulate discharge control. Typical annual costs range from $8 to $12 per ton of refuse processed. These quoted costs do not include any allowance for potential revenue from the sale of steam or electric power because the market for those products is limited at this time.

Transfer

Transfer stations provide a means of reducing the costs for transportation of refuse between the point of collection and the point of processing or disposal. Although it is necessary to have a relatively large number of vehicles of different sizes to serve the refuse collection needs of an airport complex, it may prove costly to have each of those vehicles transport its load to the processing or disposal point.

To make the use of a transfer station economically feasible, the savings in transportation costs must be at least sufficient to offset the extra equipment and handling costs. Transfer stations will naturally be more economical for systems utilizing multi-man collection crews than for systems with one-man crews, depending on the hauling distance.

Transfer costs are dependent upon the type of facility constructed. A typical cross-section view of a small transfer station for airport use is shown on Figure 6. Total annual costs (composed of operation and maintenance expenses plus amortization of capital costs) range from $0.35 to $2.60 per ton of capacity, excluding the capital cost of transport vehicles. The higher costs include compaction equipment, a building, and dust collection equipment.

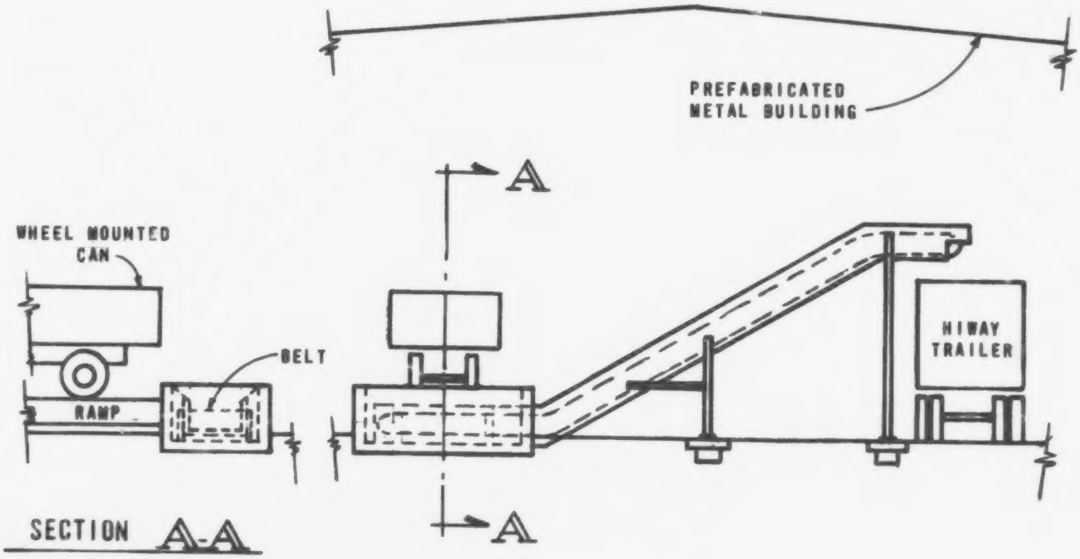

PREFABRICATED METAL BUILDING
A
WHEEL MOUNTED CAN
BELT
RAMP
HIWAY TRAILER
A
SECTION A-A

FIG. 6

TYPICAL CROSS-SECTION VIEW OF SMALL TRANSFER STATION

Chapter 6

ALTERNATIVE COLLECTION SYSTEMS

Present and Future Demands for Solid Waste Systems

The existing demand for an efficient waste collection and removal system is evident from the quantities (average of 287.3 tons per week) measured and reported in Chapter 3. Collection equipment can be selected and the associated manpower can be planned for under these existing conditions. However, the equipment and equipment locations selected on the basis of present waste quantities of systems might become inadequate as quantities increase in the future. To assist in planning, therefore, San Francisco International Airport specified that system evaluation be done for a period up to 1985.

Future demands for solid waste systems were projected to 1985 based on projected passenger loadings and air cargo tonnage to that time. The future refuse quantities are shown on Figure 7. The quantities were derived by multiplying future passenger loadings, air cargo tonnage, and maintenance base employees by solid waste parameters (pounds per passenger, pounds per ton of cargo, and pounds per employee) developed during the weighing program. The parameters are listed in Chapter 3. These projections are extremely sensitive and subject to change because of the

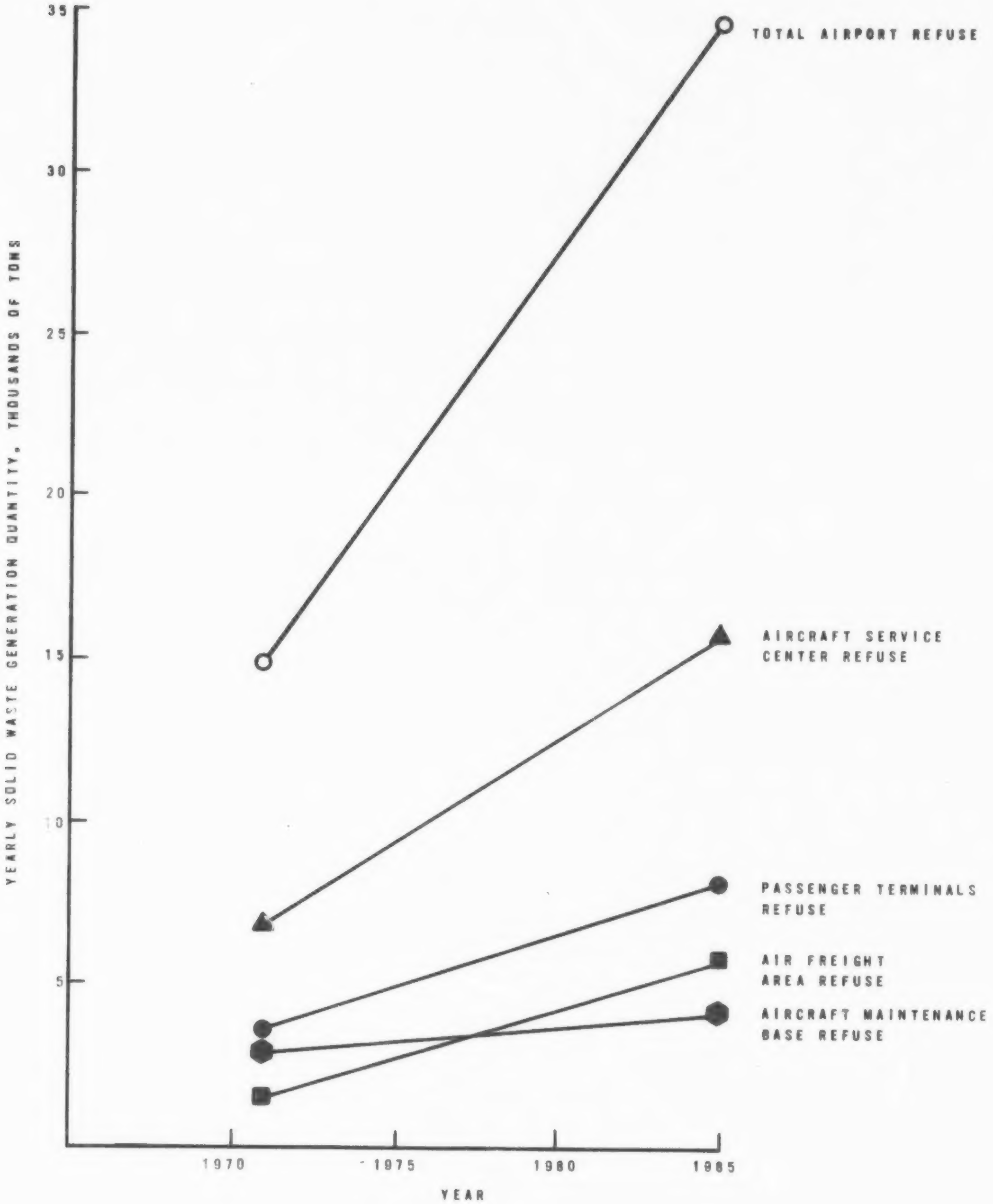


FIG. 7
PROJECTED QUANTITY OF AIRPORT REFUSE, 1970-1985

uncertainty of air travel projections. For example, passenger traffic at the airport stopped increasing in 1970, and has remained at a constant level through 1971. Because of this and the potential for changes in flight equipment, airport planning and associated projections do not often exceed a period of 5 years into the future, thereby making long-term projections difficult. For this study, the airport did provide an estimate of passenger loadings anticipated in 1985. This future estimate was used to form the projections for refuse quantities from the passenger terminals and service centers. Historical records were used to develop an annual growth rate of 10 percent in air cargo tonnage, and this rate was used to develop the projection for refuse from the air freight area. Finally, maintenance base refuse projections were made on the basis of a 5-year employee growth rate extended at a constant level through 1985.

Solid wastes requiring special handling (sewage sludge, demolition material, and industrial sludges) will continue to exist on the airport complex throughout the period. The quantity of sewage sludge is estimated to be 850,000 gallons per year today and is projected to increase to 1,820,000 gallons per year by 1985. Demolition materials were not measured during this study, and an estimate of annual quantities could not be obtained. The quantity is large, and should continue to be handled in the existing manner. Industrial sludges and contaminated oils are presently generated at a rate in excess of 500,000 gallons per year. Future quantities are projected to remain at that level. Although this study did not fully evaluate equipment to handle these special wastes, a brief commentary is appropriate. The alternative methods for disposal of industrial wastes are becoming very limited, thereby increasing disposal costs significantly. In the future, processing and treatment at the source will become economically desirable. When this happens, collection equipment will change. For the present, the industrial tank trucks and open dump trucks should continue in use.

Selected Collection and Handling Methods

Potential collection and handling methods were identified in Chapter 5. Each of these methods was subjected to a technical and economic evaluation based upon present and future conditions at the airport. The economic evaluation was based upon unit costs ($ per ton of refuse) and capital costs. The technical evaluation included construction, operation, and demonstrated capability of solid waste systems under airport conditions. Table 8 shows the unit and capital costs for the collection and handling equipment for which cost information was obtained. Cost information was not available for the dry vacuum transport system because complete technical information on the system is only now becoming available. Also, the back-end loader vehicle-container system was not

Table 8

COLLECTION AND HANDLING EQUIPMENT COSTS

Item	Unit cost,(1) $ per ton	Capital cost,(2) $	Estimated useful life, years
In-house collection			
Rolling cans - 2-cy capacity	5.69	400	10
Storage			
Stationary compactor (10-ton/day capacity) with debris box - 40-cy capacity	1.33	17,500	15
Debris box - 20-cy capacity	0.23	1,950	10
Wheel mounted cans (uncompacted) - 4-cy capacity	1.58	775	8
Wheel mounted cans (compacted) - 5-cy capacity	1.11	3,000	10
Collection vehicle			
Front-end loader - 30-cy capacity	2.29	31,000	8
Towing tractor - 2-container (compacted) capacity	2.01	3,000	8
Tilt-frame truck - 30-cy capacity	0.99	23,650	8
Processing			
Shredder - 7.5-ton/hr capacity	1.84	21,500	15
Incinerator - 20-ton/day capacity	11.00	500,000	20
Wet pulping - 3,200-lb/hr capacity	5.80	84,700	12

Note: The equipment capacities listed were used to develop the unit costs and might not be the same capacities as selected in the final systems.

(1) Includes capital costs amortized at 6 percent interest over the estimated useful life of equipment and annual operation and maintenance costs for a typical airport system.

(2) Includes equipment cost, shipment costs to San Francisco, installation costs, and contingencies. Capital costs based on an ENR of 1900.

Source: Unit costs derived by Metcalf & Eddy; capital costs and estimated useful life derived by Metcalf & Eddy from data provided by equipment suppliers.

selected for detailed economic analysis because its efficiency in commercial types of waste systems is known to be extremely low. Its potential use was in collecting loose hand-thrown wastes, a system not considered necessary or desirable after monitoring the airport refuse generation.

The cost data from Table 8 were used initially to select combinations of collection and handling equipment that were the most beneficial to the airport solid waste collection system. The total solid waste management system, including collection, transfer, processing, and disposal, did not receive primary consideration during this analysis of beneficial collection equipment.

Potential Locations for Equipment

The storage containers and processing equipment of the system should be placed in locations (1) where they will not interfere with aircraft operations, (2) close to large quantities of refuse, (3) where they are accessible to collection vehicles, and (4) where they are accessible to the tenants delivering in-house collection containers. The most important criterion concerns aircraft operations. Airports have much open space, and the potential locations for storage containers are numerous. Locations where containers should be placed are listed as follows.

Type of storage container	Location
Stationary compactor with debris box	Alongside hangars or terminal building where power is available. Exclude from Piers A through G.
Debris box	Alongside buildings or fences. Provide wind protection where possible. Exclude from Piers A through G.
Wheel mounted cans (compacted and uncompacted)	Can be used anywhere if kept outside of aircraft movement areas.

The potential locations for processing equipment (shredding and wet pulping) are more limited. In reviewing the use of a shredder at the airport, the most beneficial use was found in processing bulky wastes. These bulky wastes are normally concentrated in the air freight area. The wet pulping system requires the installation of pumps and piping, and is most beneficial where it serves a single building or a close grouping of buildings. The potential locations are listed as follows:

Processing equipment	Location
Shredder and containers	Air freight area.
Wet pulping and containers	The main terminal garage to serve all terminals. United Air Lines maintenance base.

The final locations of containers will be determined by the management organization specifying and controlling solid waste collection systems.

Selected Management Methods

Three management methods for airport solid waste collection systems were identified in Chapter 4. Two of these methods were selected for evaluation in system development: full operational control by the airport authority (Method 1), and control shared between the tenants and the authority (Method 2). The full tenant control method (Method 3) was rejected because the quantity and characteristics of the wastes, and the increasing public concern for the environment in which solid wastes are generated, require a greater control by public officials. In addition, only an integrated management system could yield an economical operation for all airport tenants.

The present management of the solid waste collection system has been satisfactory in most areas. Only limited amounts of paper have been observed blowing, and in no case has a health hazard existed. Because the existing management has been successful in performing the refuse removal task, a change in management method would require a strong economic benefit to offset the expense of implementing changes.

System Development

Six separate equipment configurations were subjected to an economic analysis in an attempt to find the most efficient system. Table 9 shows the equipment evaluated.

From this equipment evaluation two alternative systems were derived and are presented here. Each system has a potential for economic benefit to the entire airport complex. Alternative 1 is a modification of the existing collection equipment that would improve efficiency. Management would exercise a stronger control over the refuse storage equipment used, but the collection would be done by the private hauler. Alternative 2 is a complete change from the existing system. The airport authority would purchase all storage and handling equipment and would provide complete refuse collection service.

Before describing each alternative individually, it is important to identify the guidelines considered essential to the development of both systems.

1. Flexibility. Because the airport must be constantly changing and adapting to new tenants, flight equipment, and passenger service, the solid waste collection system must be flexible. In the past, the airport has undergone major reconstruction on a 5-year cycle. Solid waste collection systems permanently installed, with a normal 15-year capital write-off period, may be obsolete or require relocation after only 5 years.

Table 9

EQUIPMENT EVALUATED FOR USE AT SAN FRANCISCO INTERNATIONAL AIRPORT

Configuration	In-house collection	Storage with or without processing	Transport vehicle
1	Wet pulping system	Debris box	Tilt-frame truck*
2	Rolling containers*	Debris box (stationary compactor)*	Tilt-frame truck*
3	Rolling containers*	Debris box (stationary compactor)* Shredding at air freight area	Tilt-frame truck*
4	Rolling containers*	Wheel mounted cans (compacted)	Towing tractor
5	Rolling containers*	Wheel mounted cans (uncompacted)	Towing tractor
6	Rolling containers*	Front-end loading containers*	Front-end-loader truck*

*Equipment presently used.

2. Non-interference with Aircraft Operations. The loading piers, aprons, taxiways, and runways are reserved for aircraft movement. The transfer of refuse from a storage container to a collection truck should be prevented in those areas.

3. In-house Handling. Most major airlines at the airport have ground support vehicles which handle the materials entering the solid waste systems. Maximum utilization of these in-house vehicles to deliver wastes to central collection containers is desirable.

The two alternatives are described in the following subsections.

Alternative 1

The collection equipment and its approximate locations are shown on Figure 8. The most significant feature of this system is the abandoning of 38 front-end loading containers and 60 back-end loading containers and the consolidation of refuse formerly stored in those containers into 7 compacted and 5 uncompacted debris boxes. The locations shown for the containers are only approximate. Exact locations would depend on power availability at compactor locations and generally clear access at all locations. The removal of all existing front-end and back-end loading containers is economically feasible since the private hauler owns them.

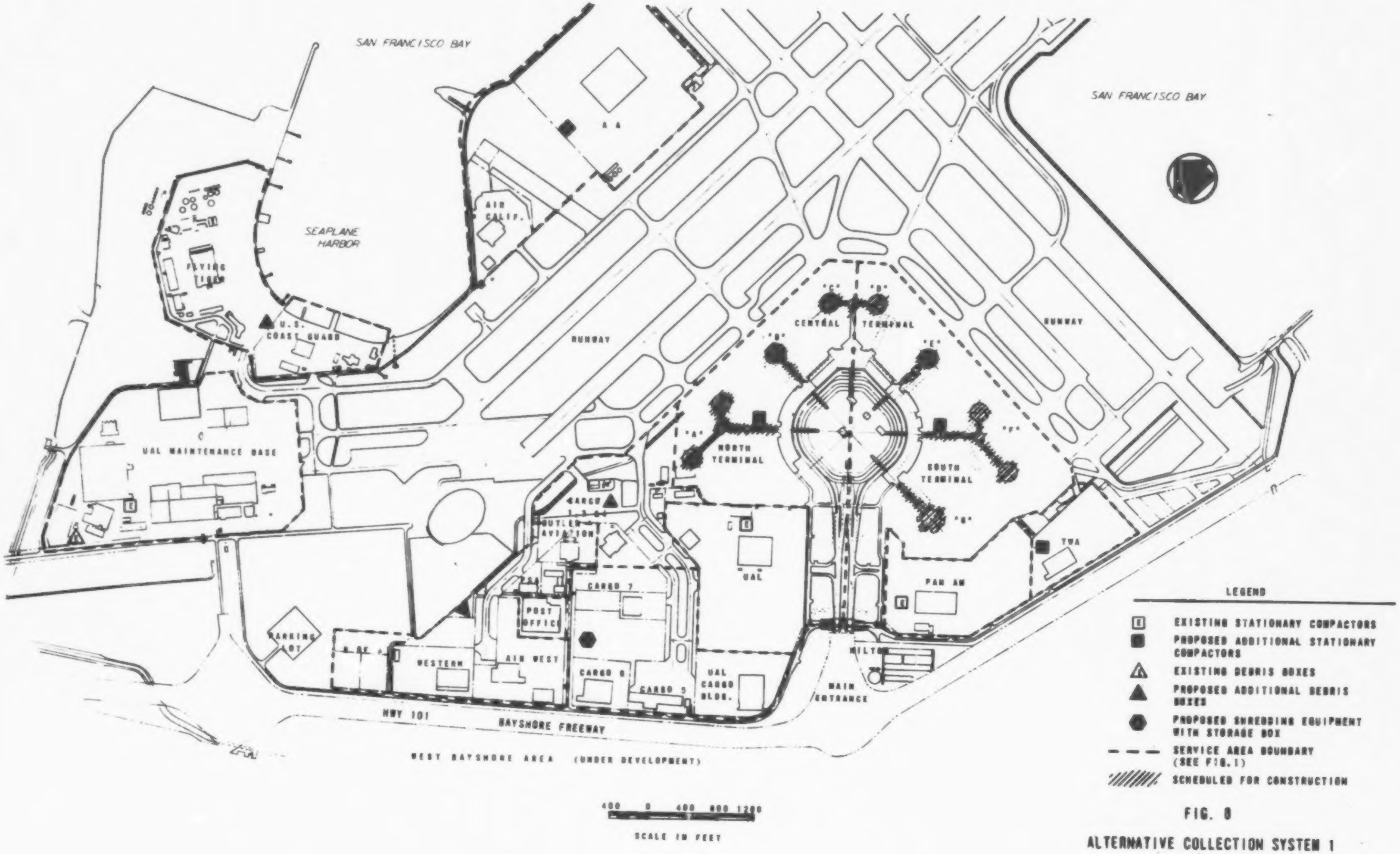

SAN FRANCISCO BAY
SAN FRANCISCO BAY
SEAPLANE HARBOR
FLYING TIGER
U.S. COAST GUARD
UAL MAINTENANCE BASE
A A
AIR CALIF.
RUNWAY
RUNWAY
CENTRAL TERMINAL
NORTH TERMINAL
SOUTH TERMINAL
"A"
"B"
"C"
"D"
"E"
"F"
"G"
CARGO
OUTLET AVIATION
CARGO 7
POST OFFICE
CARGO 6
CARGO 5
UAL CARGO BLDG.
UAL
PAN AM
TWA
HILTON
MAIN ENTRANCE
PARKING LOT
WESTERN
AIR WEST
HWY 101
BAYSHORE FREEWAY
WEST BAYSHORE AREA (UNDER DEVELOPMENT)
400 0 400 800 1200
SCALE IN FEET
LEGEND
EXISTING STATIONARY COMPACTORS
PROPOSED ADDITIONAL STATIONARY COMPACTORS
EXISTING DEBRIS BOXES
PROPOSED ADDITIONAL DEBRIS BOXES
PROPOSED SHREDDING EQUIPMENT WITH STORAGE BOX
SERVICE AREA BOUNDARY (SEE FIG.1)
SCHEDULED FOR CONSTRUCTION

FIG. 8

ALTERNATIVE COLLECTION SYSTEM 1

A shredder has been located in the air cargo area to reduce the volume of bulky air freight wastes. Again, the delivery of wastes to the shredder would be an in-house collection task for each tenant. The shredder is to receive only wood pallets and bulky nonmetal packing materials. It would be operated by each tenant as he delivers bulky wastes. The economic importance of the shredder is small, and if tenants object to preparing and delivering bulky wastes to this facility it can be deleted from the system. Three open uncompacted debris boxes should be substituted if the shredder is not installed.

The implementation of this system could be accomplished only through strong control by the airport authority. Most smaller tenants will not see an immediate benefit, and therefore will not react favorably to change. In addition, a degree of convenience is lost because the storage container will no longer be outside the door of each tenant. The final configuration of the total number of containers and container locations must be worked out with each tenant at the time of system implementation.

Capital costs and operating personnel requirements are shown in Table 10. The capital requirements are high while manpower requirements are low. Capital costs have been amortized at 6 percent and combined with estimated annual operation and maintenance costs to form an estimated annual system cost of $5.20 per ton of refuse collected.

Table 10

EQUIPMENT AND MANPOWER REQUIREMENTS AND CAPITAL COSTS FOR ALTERNATIVE 1

Item	Amount of equipment needed	Manpower for operation	Capital costs $
In-house collection			
As practiced by each tenant	N.I.(1)	N.I.	N.I.
Storage			
Stationary compactor (with debris box)	7(2)	0.5(3)	208,000
Debris box (uncompacted)	5	-- (4)	9,000
Collection vehicle			
Tilt-frame truck	2	2	47,000
Processing			
Shredder	1	-- (3)	38,000
Total		2.5	302,000

(1) N.I. - no information.

(2) Compactors already owned and used are capitalized at new cost here.

(3) One man needed half-time for all equipment maintenance.

(4) Operator of collection vehicle handles debris boxes.

Since the container locations and containers are controlled by the airport, the contract for collection of refuse from the airport complex must be administered by the airport. The contractor would be paid by the airport on the basis of refuse hauled, and tenant costs would be billed by the airport as sewage and other utilities are billed now. With centralized containers and no means of keeping records on the actual quantity of refuse generated by each tenant, billings to the tenant should be based on monthly air passengers and cargo. The weight parameters of pounds per passenger per day and pounds per ton of cargo, as described in Chapter 3, are sufficiently accurate to be used for billing purposes. Smaller waste sources (such as car rental agencies) not directly involved in air passengers or cargo, would be charged an equitable flat rate.

The advantages of Alternative 1 over the existing system are summarized as follows:

- Present collection trips could be reduced from 70 trips per week to 54 trips per week, and total time consumed in the airport collection could also be cut approximately by 50 percent (from 51 hours to 24 hours).

- Lower annual costs would result for all tenants collectively, although each individual tenant might have a higher or lower cost, depending on present in-house collection equipment and contract arrangements.

- Potential interference with aircraft movement would be greatly reduced.
- Security within aircraft operating areas would be more easily maintained.
- Refuse would be delivered to a limited number of collection locations by each tenant, thereby utilizing to a greater degree the in-house equipment (and its flexibility for both refuse hauling and aircraft operations) of each tennant.

Alternative 2

The collection equipment of Alternative 2, and its approximate locations, are shown on Figure 9. The most significant feature of the system is the complete change in containers and vehicles from the existing system. All existing storage equipment would be replaced by wheel mounted containers, and multiple containers would be collected and transported in a single train by a small powered tractor. The points for container location shown on Figure 9 represent the center of refuse collection for the service area shown, not a single container. The actual number of containers needed to store and transport the refuse is shown in Table 11, along with the total system cost.

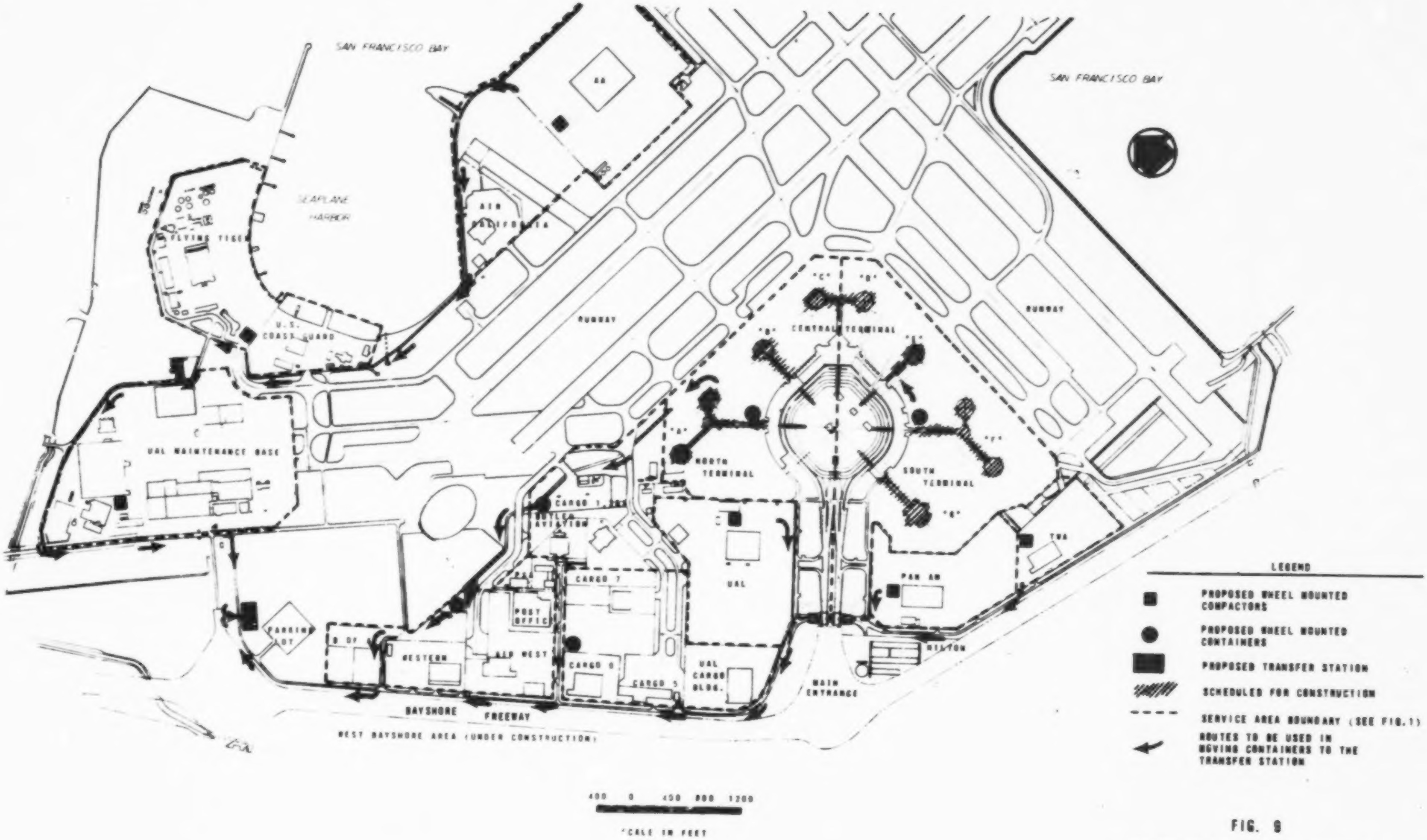

SAN FRANCISCO BAY
SAN FRANCISCO BAY
SEAPLANE HARBOR
FLYING TIGER
U.S. COAST GUARD
AIR CALIFORNIA
AA
RUNWAY
RUNWAY
UAL MAINTENANCE BASE
"A"
"B"
"C"
"D"
"E"
"F"
"G"
CENTRAL TERMINAL
NORTH TERMINAL
SOUTH TERMINAL
CARGO 1
CARGO 7
CARGO 6
CARGO 5
POST OFFICE
AIR WEST
WESTERN
UAL
UAL CARGO BLDG.
PAN AM
TWA
HILTON
MAIN ENTRANCE
PARKING LOT
BAYSHORE FREEWAY
WEST BAYSHORE AREA (UNDER CONSTRUCTION)
LEGEND
■ PROPOSED WHEEL MOUNTED COMPACTORS
● PROPOSED WHEEL MOUNTED CONTAINERS
■ PROPOSED TRANSFER STATION
▨ SCHEDULED FOR CONSTRUCTION
- - - SERVICE AREA BOUNDARY (SEE FIG.1)
ROUTES TO BE USED IN MOVING CONTAINERS TO THE TRANSFER STATION
400 0 400 800 1200
SCALE IN FEET

FIG. 9

ALTERNATIVE COLLECTION SYSTEM 2

Table 11

EQUIPMENT AND MANPOWER REQUIREMENTS AND CAPITAL COSTS FOR ALTERNATIVE 2

Item	Amount of equipment needed	Manpower for operation	Capital costs $
In-house collection			
As practiced by each tenant	N.I.(1)	N.I.	N.I.
Storage			
Wheel mounted cans (uncompacted)	48	-- (2)	36,000
Wheel mounted cans (compacted)	5	-- (2)	38,000
Collection vehicle			
Towing tractor	4	3	12,000
Transfer			
Station	1	1	32,000
Truck and trailer	1	1	46,000
Total		5	164,000

(1) N.I. - no information.

(2) Operator of vehicle handles wheel mounted cans.

Since the wheel mounted containers considered here are not constructed for operating at speeds over 15 to 20 miles per hour, it is not feasible to transport the individual containers long distances to a disposal site. Therefore, a transfer station has been located on the airport at which each small container can be emptied into a single larger trailer for movement to the disposal site. The station has the capacity to handle all present solid wastes, and would be capable of handling all wastes generated through 1985. The location of the station as shown on Figure 9 is approximate. If moved to another place, it should be located so that access for the small wheel mounted containers is good, and also so that the large transfer trailer and tractor have good access to the freeway.

The implementation of this system would be accomplished under full operational control by the airport. The airport utility staff would be expanded to provide the container pickup service, operate the transfer station, and operate the transfer truck between the airport and the disposal site. The number of people needed to operate the system is shown in Table 11. A small garage and equipment storage space would be needed in the same location as the transfer station. As in Alternative 1, the in-house collection system of the tenants would be used to the maximum degree possible in Alternative 2. The wheel mounted containers would be grouped in the locations shown, and each tenant would use in-house collection to deliver solid wastes to that location. The airport collection crew would then come to the collection point on a preset schedule, attach all filled containers to the powered tractor and, following the routes shown on Figure 9, deliver the containers to the transfer station.

The capital cost is shown in Table 11. Capital costs are low while manpower requirements are high. Capital costs have been amortized at 6 percent and combined with estimated annual operation and maintenance costs to form an estimated annual system cost of $5.60 per ton of refuse collected and delivered to a transfer vehicle.

The billing of tenants to cover the cost of installing and operating the solid waste collection system would be done by the airport. Each tenant should be billed in relation to the wastes generated. As described in Alternative 1, this could be done on the basis of air passengers and cargo handled during the billing period.

The advantages of Alternative 2 over the existing system are summarized as follows:

- Solid wastes technology is presently evolving at a very rapid rate. More efficient processes may soon be developed. This alternative would be most flexible for adapting to future change.

- Through an integrated management system operated exclusively by the airport, tenants would collectively benefit from lower annual costs and also from future changes in technology that might require a large amount of investment to update the system.

- Although the collection time and number of pickups would be nearly equivalent to the existing system, airport security would be increased under Alternative 2 because airport personnel would be operating on collection routes. Interference with aircraft operations would also be minimized because the towing tractors and containers are approximately the same size as baggage handling equipment widely used around aircraft.

Cost Analysis

The capital and operation and maintenance costs for each alternative collection system were developed in preceding sections. These values were then compared to the present system costs in an attempt to establish economic benefit by implementing system modifications.

The present system costs were derived from data supplied by the private hauler. To verify those costs, each tenant was requested to provide the total cost of refuse collection for July and August 1971. The results of summing tenant data verified the billings supplied by the hauler. The annual costs were divided by the total annual weight of refuse collected (total weekly weight was measured during this study) to obtain a unit cost of collection. The unit cost of the present system was computed to be $16.10 per ton of refuse collected. This is a cost for refuse collection (including a lease charge for most containers on the airport), transportation, and disposal. It cannot be compared directly with costs for Alternatives 1 and 2 without identifying the transportation and disposal costs.

The private hauler reported a disposal fee of $3.48 per ton. Assuming a transportation charge of $4.00 per ton (a high figure to give the present system the greatest advantage), the total disposal and transportation cost to be deducted from the present system cost was $7.48 per ton. The estimated collection cost under the present system, then, is $8.63 per ton (say $8.60).

A comparison of the unit costs is shown in the following tabulation:

	Unit cost, $/ton collected
Alternative 1	5.20
Alternative 2	5.60
Present system	8.60

It can be seen that a potential benefit of $3.40 per ton exists for Alternative 1 over the present system, and a benefit of $3.00 per ton exists for Alternative 2 over the present system.

At the present refuse generation rate of 14,900 tons per year, Alternative 1 has an annual benefit of $51,000 per year. Expressed as a percentage of present costs, this would be a 21 percent reduction in costs. Projecting refuse quantities and cost to 1985, Alternative 1 would be handling 34,900 tons per year at $3.40 per ton less, or a benefit by 1985 of $120,000 per year.

The annual costs and cost savings for two periods (1971 and 1985) under the existing system, Alternative 1, and Alternative 2 are shown in the following tabulation.

	For 1971 refuse quantity(1)	For 1985 refuse quantity(2)
Existing system		
Annual cost	$128,700	$302,000
Alternative 1		
Annual cost	77,700	182,000
Annual savings compared with existing system costs	51,000	120,000
Alternative 2		
Annual cost	83,200	195,000
Annual savings compared with existing system costs	45,500	107,000

---

(1) 14,900 tons per year for 1971.

(2) 34,900 tons per year for 1985.

Conclusion

A phased schedule of improvements is not presented here because such a schedule is difficult to develop and coordinate under the present conditions of fragmented control. The study scope was not broad enough to include an evaluation of each tenant, his waste generation, and his improvements in collection so that individual benefit is achieved.

The airport complex cost benefits that could be achieved in either system are large enough to warrant a serious consideration of modifications to the existing collection system. The primary consideration in undertaking system modifications is not entirely one of economics or available capital, but rather strong airport control of solid waste management so that a combination of unimpeded operations, strong security, and economy is obtained. As an example, under present management control, the obvious benefits of installing a large, efficient compaction unit cannot be realized if a tenant does not want it. Yet, the benefit is there. The airport should take action with respect to both management and equipment. This can be accomplished under either Alternative 1 or 2.

The changes in equipment that have shown a potential for benefit are related to container size and location. The equipment with the greatest benefit potential for the collection system has been identified in Alternatives 1 and 2. The final determination of the alternative to be used should be based upon the degree of operational control the airport wishes to maintain over refuse collection. With either alternative, however, the airport authority should play a stronger future role in controlling its solid waste system.

Appendix A

WEIGHING AND SAMPLING TECHNIQUES

Weighing Method

The weighing program was planned on the basis of the existing collection system. The objective was to determine the total weight of waste generated and the quantity generated by each of four major types of airport facilities. Therefore, the program included weighing every refuse truck serving the airport. Since the present collection routes vary with the quantity of refuse generated every day, close coordination with the private hauler was maintained. A semi-permanent weighing station was set up at a convenient location for the haulers, and all refuse trucks were weighed upon entering and again upon leaving the airport premises. Since most refuse collection takes place at night, the working hours of the weighing team were from 10:30 p.m. to 9:00 a.m. Collections made during other times of the day, such as those from debris boxes and special accounts, were weighed individually upon notification by the haulers.

Some trucks collected only from one of the four major types of airport facilities, and for these trucks it was sufficient to record their incoming and outgoing weights, and the source of their wastes. Other trucks, however, collected from several different types of facilities. To determine the portion of their loads attributable to each type, it was necessary to follow them with portable scales and weigh them after each facility stop. Accordingly, two two-man teams were used to accomplish the entire weighing program--one team at the semi-permanent weigh station and one team following individual trucks to identify their refuse collection routes and weigh them at intermediate collection points.

The weighing program was accomplished in a one-week period during the summer of 1971. The results were summarized and are shown in Chapter 3 (Table 3).

The weighing for the aircraft wastes was conducted by direct measurement of wastes removed from the flight by the service crew. Since it was not practical to obtain samples from all airlines, United Air Lines, Pan Am, TWA, and Western Airlines were selected as typical carriers to be sampled. The factors that determine the quantity and the composition of aircraft passenger wastes are considered to be: (1) the number of passengers, (2) time of flight, (3) distance of flight, (4) number of meals served on board, and (5) type of aircraft. In order to facilitate identification of these factors, each sample was weighed and identified by flight number. The results are presented in Chapter 3 (Table 4).

Sampling Methods

The sampling program was set up so that statistically sound data would be obtained within the funding limitations of the study. Based upon previous sampling experience, 10 samples were to be taken from each of the four major sources and then subjected to physical and chemical analyses. This was an optimum number which was modified later to suit the actual airport conditions. No attempt was made to identify seasonal variation on samples because the composition of refuse from airports was not known to vary with the season.

The sampling procedures generally followed the recommended procedures of the APWA. The only modifications involved the quantity sampled and the sampling location. The quantity sampled was to be less than 500 pounds, and the sampling location was directly at the source instead of from the collection truck. The specific sampling procedures used at each source are described in the following paragraphs.

1. Passenger Terminals. The refuse storage rooms of the Central and South terminals were used as sampling rooms. Refuse from the Central and South terminals

was considered as being representative of the entire passenger terminal area, and composite samples were prepared of 60 percent Central Terminal wastes and 40 percent South Terminal wastes.

Within the Central Terminal sampling room, the space was divided into four quadrants with equal numbers of refuse containers in each quadrant. To minimize the prejudgment factor involved in selecting the wastes, each sample was restricted to one quadrant of the room without regard to the composition of the refuse in that quadrant. From the Central Terminal room, approximately 150 pounds of refuse were taken for each sample. This quantity was then separated into nine standard components, and the weight of each was recorded. The organic components were then extracted, mixed, and bagged for temporary storage.

The procedure was repeated in the South Terminal sampling room, except that approximately 100 pounds were taken from one quadrant of the room for each sample. After separation into the nine components and subsequent weighing, the organic components were extracted, mixed, bagged, and transported to the Central Terminal sampling room for mixture with the organics bagged there. After thorough mixing, the organics were quartered, and about 20 pounds were extracted from one quadrant and shredded. The shredded sample was then placed in sealed containers and taken to the laboratory for chemical analysis.

The sampling schedule for the passenger terminals was arranged to cover different collection trips during a 2-week sampling period from July 16 through July 29. Ten composite samples were taken, and the results are shown in Table A-1, which lists the weight of each component in each sample and the percent by weight of each component. The mean value of each component was then computed to present a representative pattern of component distribution. Variance and standard deviation were calculated to determine the dispersion of the sampled data.

Since the sampling program was designed to obtain representative results through random sampling, the distribution of sampled data was assumed to be normal. With this assumption, the confidence ranges of the data that would result in a 95 percent confidence range of normal distribution using 10 samples were identified and are shown in Table A-2.

Table A-1

SAMPLING DATA - QUANTITIES OF SOLID WASTES FROM PASSENGER TERMINALS BY COMPONENT
San Francisco International Airport, July 1971

Component \ Sample no. & date	1 7/15	2 7/16	3 7/19	4 7/20	5 7/21	6 7/22	7 7/23	8 7/26	9 7/27	10 7/28	Total
	Pounds										
Paper & paper products	238	201	188	206	205	173	202	175	210	193	1,991
Plastics	17	19	13	10	6	13	7	19	13	30	147
Food wastes	43	23	21	11	15	10	11	14	9	5	162
Wood & wood products	9	0	11	8	7	21	15	7	5	4	87
Trimmings	0	0	0	5	1	0	0	0	0	0	6
Metal & cans	53	21	14	15	7	18	8	21	14	14	185
Glass, stone & ceramics	49	9	11	5	0	10	5	26	9	7	131
Dirt & demolition materials	15	11	8	3	4	3	4	5	2	3	58
Miscellaneous	28	10	13	3	14	7	9	10	5	6	105
Total	452	294	279	266	259	255	261	277	267	262	2,872
	Percent										Mean value
Paper & paper products	53	68	67	78	79	68	77	63	79	74	71
Plastics	4	6	5	4	2	5	3	7	5	12	5
Food wastes	10	8	8	4	6	4	4	5	3	2	5
Wood & wood products	2	0	4	3	3	8	6	3	2	2	3
Trimmings	0	0	0	2	0(2)	0	0	0	0	0	0(2)
Metal & cans	12	7	5	6	3	7	3	8	5	5	6
Glass, stone, & ceramics	11	3	4	2	0	4	2	9	3	3	4
Dirt & demolition materials	3	4	3	1	2	1	2	2	1	1	2
Miscellaneous	6	3	5	1	5	3	3	4	2	2	3
Total(1)	100	100	100	100	100	100	100	100	100	100	100

(1) Figures may not add due to rounding.

(2) Less than 0.5 percent.

Table A-2

SAMPLING DATA - CONFIDENCE RANGE ON DATA FROM PASSENGER TERMINALS BY COMPONENT
San Francisco International Airport, July 1971

Component	Mean value (%)	Variance (%)	Standard deviation (%)	Number of samples taken	Confidence (%)	Confidence range (%)	
						From	To
Paper & paper products	70.6	71.2	8.4	10	95	65.4	75.8
Plastics	5.3	7.0	2.6	10	95	3.6	7.0
Food wastes	5.3	5.5	2.3	10	95	3.8	6.8
Wood & wood products	3.3	5.5	2.3	10	95	3.8	6.8
Trimmings	0.2	0.3	0.5	10	95	0	1.5
Metal & cans	6.1	6.6	2.5	10	95	4.4	5.8
Glass, stone, & ceramics	4.1	11.4	3.3	10	95	2.0	6.2
Dirt & demolition materials	1.8	1.1	1.0	10	95	1.2	2.4
Miscellaneous	3.3	2.6	1.6	10	95	2.3	4.3

These ranges are commonly referred to as the result range and are widely used in engineering reports. The statistical method used generally follows standard statistical procedures. The formulas are:

$$S = \frac{\Sigma(y - \bar{y})^2}{n - 1}$$

where

S = standard deviation

y = value for each discrete sample, expressed in percent by weight

$\bar{y}$ = mean value for all samples taken, expressed in percent by weight

n = total number of samples taken

and

$$P\,(|\Sigma_{\bar{y}}| \geq \delta) \leq \alpha$$

where

$\Sigma_{\bar{y}}$ = the random variable associated with sample mean, or $\Sigma_{\bar{y}} = \bar{y} - y$

δ = positive scalar which is equal to h times of the standard error of sample mean, $\frac{h\,s}{\sqrt{n}}$. In the case of 95 percent confidence range, h=1.96.

α = probability of error for the desired confidence range. For 95 percent confidence, α is equal to 0.05.

2. Air Freight Area. The refuse generation from the air freight area is spread over a wide cargo area, with no single source being representative of all sources. Accordingly, composite samples included the refuse generated by all tenants. Depending upon availability of refuse from each tenant at the time of collection for sampling, each composite sample contained roughly equal proportions of refuse from each tenant. General procedures for quartering, separating, and weighing the refuse were the same as described for the passenger terminals. The sampling was completed from July 16 through July 29. Ten composite samples of approximately 250 pounds each were analyzed. Statistical testing was performed as described for the passenger terminals. The results are shown in Tables A-3 and A-4.

3. Aircraft Service Centers. Service center wastes consist of wastes from flight kitchens, aircraft, and service buildings.

   Sampling was done from two sources within the service center, with 5 samples from service buildings and 27 samples from aircraft. Of the 27 aircraft samples, 11 were taken from aircraft with

Table A-3

SAMPLING DATA - QUANTITIES OF SOLID WASTES FROM AIR FREIGHT AREA BY COMPONENT
San Francisco International Airport, July 1971

Sample no. & date / Component	1 7/15	2 7/16	3 7/19	4 7/20	5 7/21	6 7/22	7 7/23	8 7/26	9 7/27	10 7/28	Total
	Pounds										
Paper & paper products	182	140	162	85	82	122	162	81	131	102	1,249
Plastics	21	11	25	29	17	46	26	18	60	25	278
Food wastes	9	5	6	24	11	6	3	12	7	3	86
Wood & wood products	15	13	19	31	58	36	40	65	84	109	470
Trimmings	0	8	15	15	7	20	0	5	1	0	71
Metal & cans	12	15	10	18	56	28	18	42	3	8	210
Glass, stone, & ceramics	4	20	5	7	9	8	7	10	7	12	89
Dirt & demolition materials	11	41	7	18	4	12	5	4	20	1	123
Miscellaneous	13	25	4	48	28	16	4	24	1	2	165
Total	267	278	253	275	272	294	265	261	314	262	2,741
	Percent										Mean value
Paper & paper products	68	50	64	31	30	42	61	31	42	39	46
Plastics	8	4	10	11	6	16	10	7	19	10	10
Food wastes	3	2	2	9	4	2	1	5	2	1	3
Wood & wood products	6	5	8	11	21	12	15	25	27	42	17
Trimmings	0	3	6	5	3	7	0	2	0(2)	0	3
Metal & cans	5	5	4	7	21	10	7	16	1	3	8
Glass, stone, & ceramics	2	7	2	3	3	3	3	4	2	5	3
Dirt & demolition materials	4	15	3	7	2	4	2	2	6	0(2)	4
Miscellaneous	5	9	2	18	10	5	2	9	0(2)	1	6
Total(1)	100	100	100	100	100	100	100	100	100	100	100

(1) Figures may not add due to rounding.

(2) Less than 0.5 percent.

Table A-4

SAMPLING DATA - CONFIDENCE RANGE ON DATA FROM AIR FREIGHT AREA BY COMPONENT
San Francisco International Airport, July 1971

Component	Mean value (%)	Variance (%)	Standard deviation (%)	Number of samples taken	Confidence (%)	Confidence range (%) From	Confidence range (%) To
Paper & paper products	45.7	206.9	14.4	10	95	36.8	54.6
Plastics	10.0	19.8	4.4	10	95	7.3	12.7
Food wastes	3.2	5.2	2.3	10	95	1.2	5.2
Wood & wood products	17.1	127.8	11.3	10	95	10.1	24.1
Trimmings	2.6	7.0	2.6	10	95	1.0	4.2
Metal & cans	7.7	37.3	6.1	10	95	3.9	11.5
Glass, stone, & ceramics	3.3	2.8	1.7	10	95	2.3	4.4
Dirt & demolition materials	4.4	17.5	4.2	10	95	1.8	7.0
Miscellaneous	6.0	30.1	5.5	10	95	2.6	9.4

mean service wastes and 16 from aircraft without meal service wastes. The combined daily weights are summarized in Table A-5. The sampling, quartering, and weighing was done as described for passenger terminals. However, the statistical procedures for testing the data were modified because three separate sources of waste were measured at the service center during sampling. The data from each source were tested statistically, and the results are summarized in Table A-6. The results of statistical testing for each service center source are shown in Tables A-7 through A-9. The data were accumulated and presented in this way because it was felt that waste generation from all aircraft should be cataloged to the highest degree possible. After the data were accumulated, it could be seen that a breakdown of refuse composition by each source was an additional step not necessary for identifying planning criteria. General composite refuse component values for an entire service center are meaningful for planning equipment systems for an entire airport complex. Therefore, the general composite values are summarized and a mean service center value for each component is presented. The basic weight data from each source are also

Table A-5

SAMPLING DATA - QUANTITIES OF SOLID WASTES FROM AIRCRAFT SERVICE CENTER BY COMPONENT

San Francisco International Airport, August-December 1971

Component \ Sample no. & date	1 8/30	2 8/31	3 9/1	4 9/2	5 9/3	6 9/7	7 9/13	8 9/14	9 9/15	10 9/16	11 12/1	12 12/2	13 12/8	Total
	Pounds													
Paper & paper products	59	83	61	59	38	26	58	126	115	79	140	256	353	1,453
Plastics	49	38	44	2	4	9	32	50	34	11	18	40	20	351
Food wastes	198	189	178	3	0	27	139	192	42	17	0	2	22	1,009
Wood & wood products	0	0	0	0	0	0	0	0	3	0	14	80	34	131
Trimmings	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal & cans	38	40	93	1	1	12	53	60	24	15	25	59	35	456
Glass, stone, & ceramics	9	14	70	1	0	3	5	27	22	10	42	27	14	244
Dirt & demolition materials	3	2	2	3	2	0	1	4	0	1	16	9	6	49
Miscellaneous	30	3	4	0	1	1	1	6	9	2	3	47	46	153
Total	386	369	452	69	46	78	289	465	249	135	258	520	530	3,846
	Percent													Mean value(1)
Paper & paper products	15	23	14	85	83	34	20	27	46	58	54	49	66	32
Plastics	13	10	10	3	9	12	11	11	14	8	7	8	4	10
Food wastes	51	51	40	5	0	35	48	41	17	13	0	0	4	34
Wood & wood products	0	0	0	0	0	0	0	0	1	0	6	16	6	2
Trimmings	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal & cans	10	11	20	2	1	15	18	13	10	11	16	6	7	12
Glass, stone, & ceramics	2	4	15	1	0	3	2	6	9	7	6	5	3	4
Dirt & demolition materials	1	0	0	4	5	0	0	1	0	1	1	3	1	1
Miscellaneous	8	1	1	0	2	1	1	1	4	2	10	9	9	5
Total(2)	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Composite samples 1, 2, 3, and 8 are the waste samples from meal-served flights; composite samples 4, 5, 6, 7, 9, and 10 are the waste samples from non-meal flights; and composite samples 11, 12, and 13 are the waste samples from service buildings.

(1) Mean values were computed by using the method shown in Table A-6.

(2) Figures may not add due to rounding.

Table A-6

SAMPLING DATA - PERCENT DISTRIBUTION OF WASTES COMPRISING AIRCRAFT SERVICE CENTER WASTES BY COMPONENT
San Francisco International Airport, August-December 1971

	Aircraft wastes				
Component	Mean of 11 samples of aircraft meal service wastes	Mean of 16 samples of aircraft wastes excluding meal service wastes	Composite aircraft wastes (1)	Service building wastes	Composite service center wastes (2)
Paper & paper products	20.6	84.0	23.8	57.1	32.1
Plastics	12.0	5.5	11.7	6.0	10.3
Food wastes	46.3	2.8	44.1	1.8	33.6
Wood & wood products	0	0	0	9.9	2.5
Trimmings	0	0	0	0	0
Metal & cans	13.0	1.4	12.4	10.4	11.9
Glass, stone, & ceramics	4.0	0.6	3.8	4.4	4.0
Dirt & demolition materials	0.6	4.6	0.8	1.4	0.9
Miscellaneous	3.5	1.0	3.4	9.0	4.7
Total	100.0	100.0	100.0	100.0	100.0

(1) Composite aircraft meal service wastes are composed of 95 percent meal service wastes and 5 percent other aircraft wastes (excluding meal service wastes). The percent distribution was obtained from weighing data.

(2) Composite service center wastes are composed of 75 percent composite aircraft wastes and 25 percent service building wastes. The percent distribution was obtained from weighing data.

Table A-7

SAMPLING DATA - CONFIDENCE RANGE ON DATA FOR MEAL SERVICE WASTES BY COMPONENT
San Francisco International Airport, August-September 1971

Component	Mean value (%)	Variance (%)	Standard deviation (%)	Number of samples taken	Confidence (%)	Confidence range (%)	
						From	To
Paper & paper products	20.6	58.4	7.7	11	95	16.1	25.1
Plastics	12.0	16.6	4.1	11	95	9.6	14.4
Food wastes	46.3	77.5	8.8	11	95	41.1	51.5
Wood & wood products	0	0	0	11	95	0	0
Trimmings	0	0	0	11	95	0	0
Metal & cans	13.0	19.4	4.4	11	95	10.4	15.6
Glass, stone, & ceramics	4.0	26.8	5.2	11	95	0.9	7.1
Dirt & demolition materials	0.6	0.2	0.4	11	95	0.3	0.9
Miscellaneous	3.5	17.8	4.2	11	95	1.0	6.0

Table A-8

SAMPLING DATA - CONFIDENCE RANGE ON DATA FOR AIRCRAFT WASTES (EXCLUDING MEAL SERVICE WASTES) BY COMPONENT
San Francisco International Airport, August-September 1971

Component	Mean value (%)	Variance (%)	Standard deviation (%)	Number of samples taken	Confidence (%)	Confidence range (%)	
						From	To
Paper & paper products	82.9	69.0	8.3	16	95	78.8	87.0
Plastics	6.1	34.2	5.8	16	95	3.3	8.9
Food wastes	1.9	22.1	4.7	16	95	0	4.2
Wood & wood products	0	0	0	16	95	0	0
Trimmings	0	0	0	16	95	0	0
Metal & cans	1.5	8.9	3.0	16	95	0	3.0
Glass, stone, & ceramics	0.4	1.2	1.1	16	95	0	0.9
Dirt & demolition materials	5.8	19.5	4.4	16	95	3.6	8.0
Miscellaneous	1.4	4.6	2.2	16	95	0.3	2.5

Table A-9

SAMPLING DATA - CONFIDENCE RANGE ON DATA FOR SERVICE BUILDINGS BY COMPONENT
San Francisco International Airport, December 1971

Component	Mean value (%)	Variance (%)	Standard deviation (%)	Number of samples taken	Confidence (%)	Confidence range (%)	
						From	To
Paper & paper products	57.1	54.5	7.4	5	95	50.6	63.6
Plastics	6.0	9.1	3.0	5	95	3.4	8.6
Food wastes	1.8	6.1	2.5	5	95	0	4.0
Wood & wood products	9.9	17.5	4.2	5	95	6.2	13.6
Trimmings	0	0	0	5	95	0	0
Metal & cans	10.4	18.2	4.3	5	95	6.6	14.2
Glass, stone, & ceramics	4.4	3.2	1.8	5	95	2.8	6.0
Dirt & demolition materials	1.4	0.3	0.6	5	95	0.9	1.9
Miscellaneous	9.0	1.3	1.2	5	95	7.9	10.1

presented, but only as a summary of daily values for each individual weighing.

4. Aircraft Maintenance Base. Five samples were taken from the United Air Lines maintenance base. These samples were taken from refuse generated in the shops and administrative areas of the base. Additional wastes are generated at the base which are not picked up and delivered to the compacted container at which sampling was done. Examples of wastes not sampled include industrial sludges and salvaged metals. Such wastes are not normally considered a part of the waste stream, and it is believed that the wastes sampled do represent those normally handled in a solid waste collection system.

   Approximately 100 containers are used in the in-house system to collect refuse from all of the shops. A sampling technique of taking 50 pounds of refuse from every tenth refuse container was used to produce a composite sample. The sorting and weighing was done from the in-house containers on-site at the compactor. Sampling was completed during the week of August 16 through August 20. The results are shown in Table A-10. Actual sample

Table A-10

SAMPLING DATA - QUANTITIES OF SOLID WASTES FROM AIRCRAFT MAINTENANCE BASE BY COMPONENT
San Francisco International Airport, August 1971

Sample no. & date Component	Pounds					
	1 8/16	2 8/17	3 8/18	4 8/19	5 8/20	Total
Paper & paper products	142	195	158	202	328	1,025
Plastics	22	40	31	22	91	206
Food wastes	30	39	87	59	85	300
Wood & wood products	1	10	15	35	53	114
Trimmings	0	0	0	0	0	0
Metal & cans	23	17	30	13	31	114
Glass, stone, & ceramics	54	25	20	27	62	188
Dirt & demolition materials	4	1	3	3	11	22
Miscellaneous	11	12	17	4	25	69
Total	287	339	361	365	686	2,038
	Percent					Mean value
Paper & paper products	50	58	44	56	49	51
Plastics	8	12	9	6	13	10
Food wastes	10	12	24	16	12	15
Wood & wood products	0(2)	3	4	10	8	5
Trimmings	0	0	0	0	0	0
Metal & cans	8	5	8	4	5	6
Glass, stone, & ceramics	19	7	6	7	9	10
Dirt & demolition materials	1	0(2)	1	1	2	1
Miscellaneous	4	4	5	1	4	3
Total(1)	100	100	100	100	100	100

(1) Figures may not add due to rounding.

(2) Less than 0.5 percent.

size for 5 samples ranged from 287 pounds to 686 pounds. This wide variation in the quantity sampled was caused by a variable number of in-house containers emptied during each day. Only 5 samples were taken since the source of the refuse was well known and extreme variations in composition were not expected. Procedures for quartering, separating, and weighing were similar to those described for the passenger terminals. Statistical testing followed the procedure described for passenger terminals. The results of statistical analysis are shown in Table A-11.

In every separated and categorized sample, a 20-pound composite mixture of the organic portions of the sample was set aside and stored in plastic bags for additional analyses. This sample was transported from the separation stations to the field laboratory for additional processing, usually within 2 hours of obtaining a sample. This refuse was then passed through a standard garden shredder (Sears Model 28526N). The shredded wastes were then mixed and quartered down to a quantity that fit into a 1-gallon can. These cans were then sealed with plastic lids and stored for chemical testing. The final sample which was tested weighed approximately 50 grams. All testing was completed within 24 hours of taking the sample.

Table A-11

SAMPLING DATA - CONFIDENCE RANGE ON DATA FROM AIRCRAFT MAINTENANCE BASE BY COMPONENT
San Francisco International Airport, August 1971

Component	Mean value (%)	Variance (%)	Standard deviation (%)	Number of samples taken	Confidence (%)	Confidence range (%)	
						From	To
Paper & paper products	50.9	29.6	5.5	5	95	46.1	55.7
Plastics	9.5	8.8	3.0	5	95	6.9	12.1
Food wastes	14.9	30.9	5.6	5	95	10.0	19.2
Wood & wood wastes	5.0	13.7	3.7	5	95	1.8	8.2
Trimmings	0	0	0	5	95	0	0
Metal & cans	5.8	4.4	2.1	5	95	4.0	7.8
Glass, stone, & ceramics	9.6	24.2	4.9	5	95	5.3	13.9
Dirt & demolition materials	0.9	0.22	0.5	5	95	0.5	1.3
Miscellaneous	3.4	1.4	1.2	5	95	2.3	4.5

Moisture content and volatile solids and ash were the parameters selected for chemical tests. The results of these tests were thought to be the most significant for evaluating processing methods that would benefit the refuse collection and transportation system. The results of these tests can be used to estimate the Btu (British thermal unit) content of refuse and to estimate the residue remaining after burning.

The laboratory procedures in Standard Methods for the Examination of Water and Wastewater, 12th Edition were used to conduct the moisture content and volatile solids and ash tests. For each sample, three identical tests were run using 50 grams for each test. The mean of the test results was then expressed as the daily sample value. All individual daily results for all samples are presented in Table A-12. It should be noted that the average values for the service center wastes are not necessarily equal to the average value of 15 samples. The composite weighting method used to derive the average is similar to the method used for developing averages for physical classification for service centers. A summary table of average values is presented in Chapter 3 (Table 6).

The values shown in Table A-12 represent moisture content and volatile solids and ash for the organic portion of wastes only. The data were accumulated in this way because

Table A-12

SAMPLING DATA - CHEMICAL CHARACTERISTICS OF ORGANIC SOLID WASTES BY SOURCE AND SAMPLE NUMBER
San Francisco International Airport, July-November 1971
Percent (mean values)

Source	Sample number	Sampling date	Moisture content %	Volatile solids %	Ash %
Passenger terminals	1	7/15/71	22.6	94.1	5.9
	2	7/16/71	17.8	93.3	6.7
	3	7/19/71	23.0	91.6	8.4
	4	7/20/71	11.1	89.5	10.5
	5	7/21/71	11.0	80.4	19.6
	6	7/22/71	16.6	87.1	12.9
	7	7/23/71	21.3	93.6	6.4
	8	7/26/71	42.6	96.3	3.7
	9	7/27/71	44.7	90.3	9.7
	10	7/28/71	42.8	92.6	7.4
	Average		25.4	90.9	9.1
Air freight area	1	7/15/71	9.2	95.4	4.6
	2	7/16/71	7.5	76.0	24.0
	3	7/19/71	9.3	95.7	4.3
	4	7/20/71	28.1	95.4	4.6
	5	7/21/71	20.1	94.6	5.4
	6	7/22/71	12.7	86.3	13.7
	7	7/23/71	24.3	78.2	21.8
	8	7/26/71	37.3	92.9	7.1
	9	7/27/71	22.8	92.7	7.3
	10	7/28/71	34.1	88.1	11.9
	Average		20.5	89.5	10.5
Aircraft service centers(1)	1	8/30/71	18.1	92.8	7.2
	2	8/31/71	37.4	91.3	8.7
	3	9/1/71	49.1	91.5	8.5
	4	9/2/71	37.4	95.7	4.3
	5	9/3/71	5.6	98.1	5.6
	6	9/7/71	50.5	93.0	7.0
	7	9/13/71	41.4	89.3	10.7
	8	9/14/71	29.7	96.3	3.7
	9	9/15/71	47.1	96.2	3.8
	10	9/16/71	31.1	90.3	9.7
	11	12/1/71	7.0	90.2	9.8
	12	12/2/71	18.2	92.5	7.5
	13	12/3/71	48.6	87.3	12.7
	14	12/7/71	5.4	89.5	10.5
	15	12/8/71	5.7	96.8	3.2
	Average(2)		28.5	91.9	8.1
Aircraft maintenance base	1	8/16/71	9.9	93.3	6.7
	2	8/17/71	8.6	94.1	5.9
	3	8/18/71	31.4	91.1	8.9
	4	8/19/71	32.5	95.7	4.3
	5	8/20/71	16.3	93.7	6.3
	Average		16.5	93.6	6.4

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(1) Composite samples 1, 2, 3, and 8 are the waste samples from meal-served flights; composite samples 4, 5, 6, 7, 9, and 10 are the waste samples from non-meal flights; and composite samples 11 to 15 are the waste samples from service buildings.

(2) Average values were computed by using method similar to that in Table A-6.

inorganic portions of the waste could not be processed through the shredder, requiring separation before processing. The sampling results have been carried forward and presented as separate data. In evaluating processing systems where both organic and inorganic materials are mixed, the inorganic residue must be included for sizing equipment. The effect on the chemical testing results if inorganics are included would be to lower the percentage of volatile solids, increase the percentage of ash, and leave unchanged the percentage of moisture content. This transformation of data can be done on the basis of the weighted quantity of inorganics in the sample.

Appendix B

SAMPLE OF SURVEY QUESTIONNAIRE

Airport Solid Waste Activity Questionnaire

Name of Airport: ____________________

Please fill out all the blanks to the best of your knowledge. If the question asked is not applicable to your operations, indicate by writing "Not Used (NU)." If there is no information available to you, please write "No Information (NI)."

Information on Your Airport Operations

Please provide the following data for the last fiscal or calendar year.

	On & Off	In & Out
1. Combined Total Number of Arrivals and Departures for:		
A. Passenger Flights		
B. Air Freight Flights		
C. Commuter Non-Meal Flights (under 500 miles)		
D. General Aviation Flights		
2. Combined Total Number of Passengers		
3. Combined Total Tonnage of Air Cargos		

4. Check the Following Types of Activities Existing in Your Airport:

- ☐ Gas Station
- ☐ Hotels
- ☐ Food Preparation
- ☐ FAA Facilities
- ☐ Gasoline & Oil Storage
- ☐ Banks
- ☐ Terminals and Parking Garages
- ☐ Aircraft Service Center Hangars
- ☐ Aircraft Overhaul Shop
- ☐ Air Cargo Operation
- ☐ Military Operation
- ☐ Sewage Treatment Plant
- ☐ Other (specify) ________

Existing Solid Waste Collection and Disposal Practice

Please check the appropriate blank pertinent to your airport practice.

Collected by:
- ☐ Private
- ☐ Public
- ☐ Airport
- ☐ Combined (specify) ________

Hauled to:
- ☐ Directly
- ☐ Transfer
- ☐ Open Dump Site
- ☐ Land Fill Site
- ☐ Incinerator
- ☐ Shredder
- ☐ Other Processing Plant (specify) ________

Disposal Site Owned by:
- ☐ Private
- ☐ Public
- ☐ Airport
- ☐ Combined (specify) ________

Distance from Airport:
- ☐ 0-10 miles
- ☐ 10-20 miles
- ☐ 20-30 miles
- ☐ 30-40 miles
- ☐ Greater than 40 miles

Disposal Site Operated by:
- ☐ Private
- ☐ Public
- ☐ Airport
- ☐ Combined (specify) ________

Are any of the solid waste collected at your airport recycled rather than disposed of?

☐ Yes
☐ No

If Yes:	Types	Quantity (pounds/month)

Present Solid Waste Collection Inventories

1. Please check the following types of storage containers used in your airport.

- ☐ a. Less than 1 cy cans or barrels.
- ☐ b. 1 to 4 cy rear loading containers.
- ☐ c. 2 to 6 cy front loading containers.
- ☐ d. 10 to 20 cy "pull-on" debris boxes.
- ☐ e. Larger than 30 cy stationary compactor containers.
- ☐ f. Open storage requiring shovelling of waste into collection trucks.
- ☐ g. Other (specify if checked) ____________________

2. To where do your passenger aircraft discharge their solid waste?

- ☐ a. Each service center hangar.
- ☐ b. Containers located at loading piers.
- ☐ c. Refuse room within the terminal.
- ☐ d. Other (specify if checked) ____________________

Information on Solid Waste Generation and Operation Costs

Please provide the following information. It is a very important part of this questionnaire. Please make an effort to estimate the values if you do not have existing records.

1. The volume or weight of solid waste generated at your airport:

Airport Activity	Estimated Monthly Volume (cy) or Weight (tons or pounds)
The Entire Airport	

If you have a breakdown of figures, please furnish the following data:

Passenger Service Terminal	
Aircraft Service Center	
Air Cargo Service	
Overhaul Shop	
Passenger Aircraft	

2. The cost of solid waste collection and disposal at your airport:

	Airport		Tenants		Combined Total All Operations	
	Monthly	Annual	Monthly	Annual	Monthly	Annual
Collection cost						
Disposal cost						
Total Solid Waste Operation Cost						

Evaluation of Present Practice and Future Plans

1. Do the solid waste collection activities interfere with flight operations at your airport?

☐ Frequently ☐ Occasionally ☐ Seldom ☐ Never

2. Considering the overall service given per dollar of cost to the airport, do you consider the collection of solid waste at your airport to be:

☐ Excellent ☐ Above Average ☐ Average ☐ Below Average ☐ Poor

3. If collection is done by private collectors, please indicate types of contractual arrangements:

☐ a. Each airport tenant contract directly with the private hauler and the airport management organization has no control of the contract or rates charged.

☐ b. Each airport tenant contract directly with the private hauler but the airport management organization retains the control of the contract or rates charged.

☐ c. The airport management organization, representing all tenants, contracts with private collectors. Each tenant preserves the right to be excluded from the contract.

☐ d. The airport management organization, representing all tenants, contracts with the private hauler. No tenant is permitted to make a separate contract with the private hauler.

4. Has the airport undertaken any solid waste studies or engaged in short or long term planning for solid waste management?

☐ Yes ☐ No

Explain briefly if you could: ______________________________

Person to be contacted for additional information:

Name ______________________ Title ______________________

Address ______________________________

Please Return to:
Mr. Robert Lee, Chief Engineer
San Francisco International Airport
San Francisco, California 94128

Appendix C

REGULATIONS

REGULATION 2, BAY AREA AIR POLLUTION CONTROL DISTRICT
(Fifth Rev., November 5, 1971)

DIVISION 4 - INCINERATION AND SALVAGE OPERATIONS

CHAPTER 1 - LIMITATIONS

§4110 SULFUR DIOXIDE. No person shall cause, let, permit, suffer, or allow the emission from any incineration operation or salvage operation of sulfur dioxide in excess of the limits provided in §§3121 and 3122, Chapter 1, Division 3.

§4110.1 No person shall cause, let, permit, suffer, or allow the emission from any incineration operation or salvage operation of hydrogen sulfide in excess of the limitations provided in §§11100 through 11102.8, Chapter 1, Division 11. *(Added by Resolution 635, effective November 5, 1971.)*

§4111 VISIBLE EMISSIONS

§4111.1 No person shall cause, let, permit, suffer or allow any emission from any incineration operation or salvage operation which does not comply with the visible emission limitations in §3110, Chapter 1, Division 3.

§4111.2 No person shall cause, let, permit, suffer or allow the emission from any incineration operation or salvage operation of particles in sufficient number to cause annoyance to any other person, which particles are sufficiently large as to be visible as individual particles at the emission point or of such size and nature as to be visible individually as incandescent particles. This section 4111.2 shall only apply if such particles fall on real property other than that of the person responsible for the emission.

§4112 PARTICULATE MATTER. *(Amended by Resolution No. 258, dated October 18, 1961.)*

§4112.1 No person shall cause, let, permit, suffer, or allow, any emission from any incineration operation or salvage operation, capable of burning not more than 100 tons of waste or salvage material per day, of particulate matter in excess of a concentration of 0.15 grain per standard dry cubic foot of exhaust gas. For the purposes of this §4112.1, the actual measured concentration of particulate matter in the exhaust gas shall be corrected to the concentration which the same quantity of particulate matter would constitute in the exhaust gas, minus water vapor, corrected to standard conditions, containing 6% oxygen by volume, and as if no auxiliary fuel had been used. *(Amended by Resolution 258, dated October 18, 1961 and amended by Resolution 635, dated November 5, 1970.)*

§4112.2 No person shall cause, let, permit, suffer, or allow, any emission from any incineration operation or salvage operation, capable of burning more than 100 tons of waste or salvage material per day, of particulate matter in excess of a concentration of 0.05 grain per standard dry cubic foot of exhaust gas. For the purposes of this 4112.2, the actual measured concentration of particulate matter in the exhaust gas shall be corrected to the concentration which the same quantity of particulate matter would constitute in the exhaust gas, minus water vapor, corrected to standard conditions, containing 6% oxygen by volume, and as if no auxiliary fuel had been used. *(Amended by Resolution 258, dated October 18, 1961 and amended by Resolution 635, dated November 5, 1970.)*

§4112.3 Calculation of the corrected concentration from the actual measured concentration shall be as given in Chapter 1, Division 8. Tests for determining compliance with §§4112.1 and 4112.2 shall be for not less than 50 minutes in 60 consecutive minutes, or 90% of the time of actual source operation, whichever is less. *(Added by Resolution 635, dated November 5, 1970.)*

§4113 HYDROCARBONS AND CARBONYLS. No person shall cause, let, permit, suffer, or allow the emission from any incineration operation or salvage operation of an exhaust gas containing a concentration of more than 25 ppm (vol) of total hydrocarbons, or a concentration of more than 25 ppm (vol) of total carbonyls. For purposes of this §4113, the actual measured concentrations of hydrocarbons and carbonyls in the exhaust gas shall be corrected to concentrations which the same quantities of hydrocarbons and carbonyls would constitute in the exhaust gas minus water vapor, corrected to standard conditions, containing 6% oxygen by volume, and as if no auxiliary fuel had been used. *(Amended by Resolution 635, dated November 5, 1970.)*

CALIFORNIA AGRICULTURAL CODE

VESSEL AND AIRCRAFT GARBAGE

Division 8

Chapter 1. Definitions

16001. Unless the context otherwise requires, the definitions in this chapter govern the construction of this division.

16002. "Aircraft" means every description of craft or other contrivance which is used, or capable of being used, as a means of transportation through the air from origins in other states or territories or in foreign countries.

16003. "Food stores" mean fruits, vegetables, or animal products which are carried as stores of vessels and aircraft and includes fruits, vegetables, or animal products which are carried in passengers' and crews' quarters.

16004. "Garbage" means waste material such as food scraps, table refuse, galley refuse, and refuse from stores of vessels and aircraft, including such waste material in passengers' and crews' quarters, which is derived, in whole or in part, from fruits, vegetables, or animal products.

16005. "Territorial waters of California" means all navigable waters of this state including all portions of the sea within its jurisdiction which are used by vessels or aircraft.

16006. "Vessel" means every description of craft or other contrivance which is used, or capable of being used, as a means of transportation in or on coastal, intercoastal, or foreign waters.

Chapter 2. General Provisions

16051. Regulations which are adopted by the director pursuant to this division shall not conflict with Agricultural Research Service of the United States Department of Agriculture orders or regulations which pertain to garbage that is derived from meats or meat products which originate in any country which is listed as a country in which there are animals which are infected with the disease known as rinderpest or with foot-and-mouth disease.

Chapter 3. Containers and Receptacles

16101. If means of incineration of, or other approved processing for, garbage are not available aboard any vessel or aircraft in the state, the master or other person that is in charge of such vessel or aircraft shall provide containers or receptacles with tight-fitting covers in which the garbage shall be retained while within the territorial waters of, or on the land in, California pending incineration or approved treatment under the supervision and pursuant to the regulations of the director.

Chapter 4. Violations

16151. It is unlawful for any person to throw, discharge, deposit, remove, or carry garbage, or cause, suffer, or procure garbage to be thrown, discharged, deposited, removed, or carried, from any vessel, aircraft, or any other vehicle into any territorial waters, or onto land within the state, except for any of the following:

(a) Immediate burning in incinerators.

(b) Approved treatment or approved disposal under the supervision and pursuant to the regulations of the director.

(c) Delivery to a garbage collector that, for the purpose of accepting garbage, is licensed by the director or by the federal government.

16152. It is unlawful for any person to retain or maintain garbage on any vessel, aircraft, or other vehicle within the state, except in tightly closed containers or receptacles and under such treatment as may be prescribed by the director.

16153. It is unlawful for any person to remove food stores from any vessel, aircraft, or other vehicle except under a permit issued by the director.

16154. It is unlawful for any person to violate, or to aid, abet, authorize, or instigate a violation of, this division.

CALIFORNIA ADMINISTRATIVE CODE

TITLE 3

Article 4. Vessel and Aircraft Garbage Disposal

770. Definitions. (a) As used in this article, all terms defined in Section 286 of the Agricultural Code shall have the same meaning as therein defined, unless a different meaning is specified in this Article or is apparent from the context.

(b) "Food stores" as defined in Section 286 of the Agricultural Code shall be construed to be applicable to any of the following when carried as stores of vessels or aircraft, including those carried in passengers' and crews' quarters: fresh fruits or fresh vegetables or animal products, except milk or the products of milk or canned, sterilized meats.

Note: Authority cited for Sections 770 to 778, inclusive: Section 286.1 Agricultural Code.

History: 1. New Sections 770 to 778 filed 5-13-46 (Register 3).

771. Retention and Maintenance on Vessels, Aircraft or Other Vehicles. Garbage may be retained on vessels, aircraft or other vehicles in tightly closed containers or

receptacles only subject to approval by the Director of Agriculture, his deputy or inspector who may at any time require such other disposal or treatment of garbage, containers, or receptacles, as he or they may deem necessary for the protection of agriculture.

772. Collection or Transportation of Discharged Garbage. No garbage shall be collected at or transported from any vessel or aircraft except for immediate disposal by an approved method without removal from the dock, pier, mole, or airport, unless the person, firm or corporation collecting or transporting such garbage holds a valid license issued by the director or by the Federal Government, permitting such collection or transportation to an approved incinerator or grinder, or for movement to sea for dumping as herein provided and all garbage so collected, transported, or otherwise moved from the dock, pier, mole or airport shall be in tight containers.

773. Segregation of Garbage Prohibited. No segregation of garbage shall be permitted at any intermediate point prior to delivery to an approved incinerator or grinder, or for movement to sea for dumping, and all garbage must be destroyed by one of the following approved methods immediately upon arrival at such incinerator, grinder or

dumping area at sea.

774. Approved Methods of Garbage Disposal. All facilities used for garbage disposal shall have been approved by the Director of Agriculture and/or the Federal Government and disposal shall be by one of the following approved methods:

(a) Complete reduction to ash by an approved method of incineration.

(b) Reduction to a liquid state by grinding and discharge into sea water.

(c) Dumping at sea at a distance from shore which will preclude the return ashore of any portion of such garbage. Such dumping shall be in compliance with the provisions of the Health and Safety Code of California.

(d) Sterilization by heat in a closed tank, chamber or cabinet for a period of two hours at a constant mass temperature not less than 212°F.

(1) The sterilization tank, chamber or cabinet shall be provided with an adequate source of steam

and equipped with a recording thermometer and a mechanical agitator to assure complete and uniform heat penetration to all parts of the mass for the duration of the exposure.

(2) Temperature records shall be retained on file for periodic checks by authorized inspectors.

(3) After sterilization, as provided in (d) above, the garbage shall be disposed of in a sanitary land fill approved by the Department.

(e) Garbage from vessels having food stores procured only in California may be disposed of in a sanitary land fill approved by the Department provided the vessels have not had contact with ports outside of California.

(f) Garbage from aircraft, derived from meals served or prepared for serving to passengers or crew while in flight, may be disposed of by grinding through an approved garbage disposal unit and discharge into a sewage disposal system acceptable to the Department.

History: 1. Amendment filed 10-8-56; effective thirtieth day thereafter (Register 56, No. 19).

2. Amendment adding new paragraph (e) filed 6-27-60; effective thirtieth day thereafter.
3. Amendment adding new paragraph (f) filed 6-11-65; effective thirtieth day thereafter.

775. Vessel and Aircraft Garbage Collector's License. Each person, firm or corporation desiring to transport or otherwise move garbage from the dock, pier, mole, or airport shall make application for and obtain a license therefor from the Director of Agriculture before engaging in such operations. All applications for such license shall be in writing on forms furnished by the Director upon request. Licenses issued pursuant to this regulation are valid until revoked by the Director.

Holders of a license from the Federal Government for the purposes stated in this section shall not be required to have a license therefor from the Director.

776. Permits for Removal of Food Stores. Permits to remove food stores, as required in Section 286.4 of the Agricultural Code, may be obtained from representatives of the Director located at offices of the State Department

of Agriculture in Sacramento, Los Angeles, San Francisco, San Diego, or San Pedro, or from the county agricultural commissioners of those counties served by maritime ports or airports located in areas other than those served by the State Department of Agriculture offices hereinabove stated.

Permits shall not be issued to authorize the removal of food stores which are restricted or prohibited entry by any order or regulation of the California or Federal Department of Agriculture.

777. Enforcing Officers. All authorized agents of the Director and all state plant quarantine officers are empowered to carry out all the provisions of these regulations.

778. Subject to Other Rules and Regulations. Compliance with the provisions of this article, governing the disposal of vessel and aircraft garbage, shall not be construed to be compliance with the provisions of any rules or regulations promulgated by any other official agency or officer or promulgated under authority of the provisions of the Agricultural Code other than Chapter 4 of Division 2 of said Code.

NOTE:

In Section 770 (a) above, Agricultural Code Section 286 referred to is now Sections 16001-16006.

In Section 770 (b) above, Agricultural Code Section 286 referred to is now Section 16003.

In Section 776 above, Agricultural Code Section 286.4 referred to is now Section 16153.

In Section 778 above, Agricultural Code Chapter 4 of Division 2 is now Division 8.

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